Engr

THE CORNELL ENGINEER

May, 1948
Vol. 13, No. 8

25 Cents
Per Copy

OLLEGE OF ENGINEERING · CORNELL UNIVERSITY

Founded 1885

The CORNELL ENGINEER

Volume 13 Number 8

CONTENTS

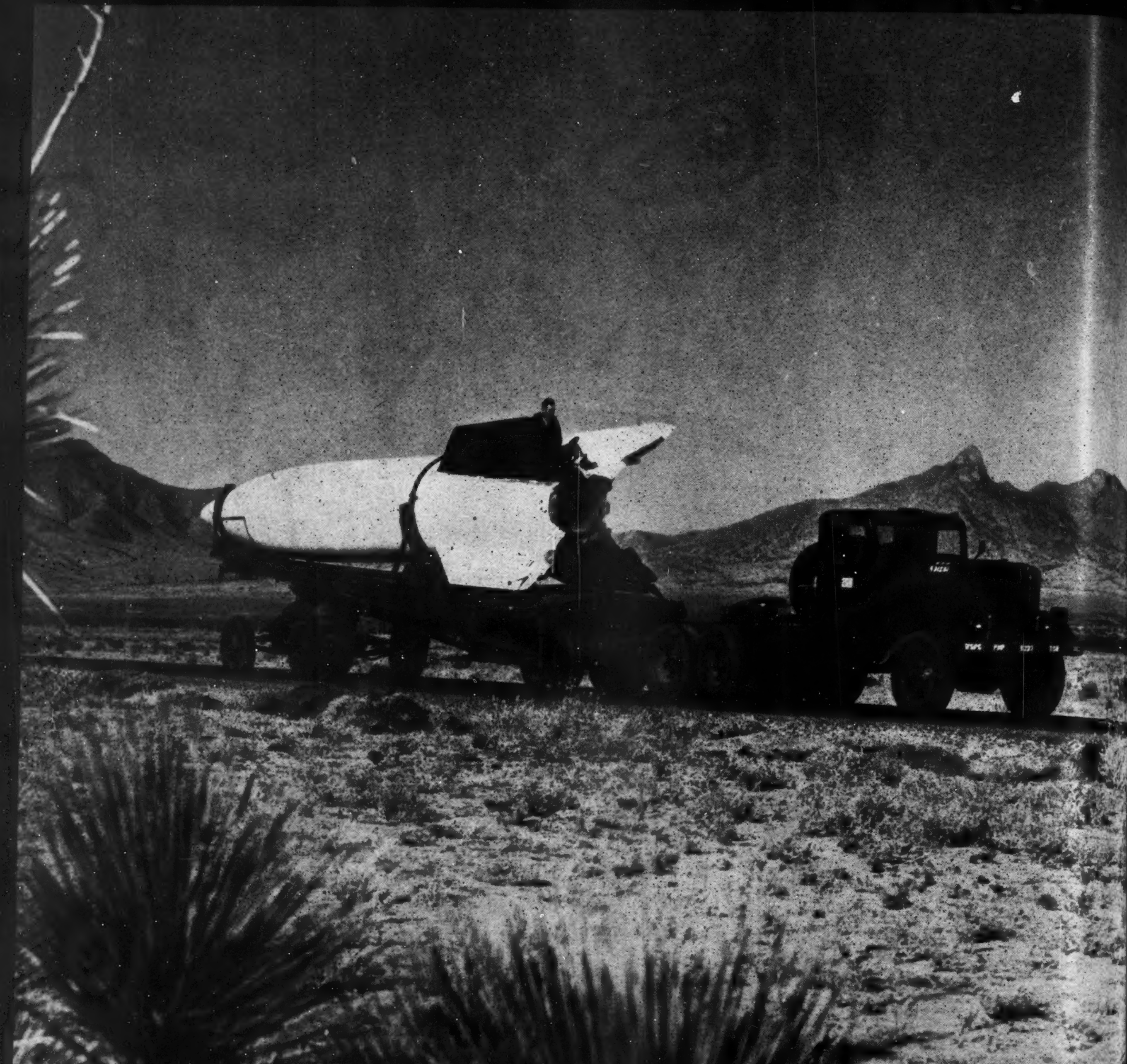
Cover: Students running a test on an Olsen 200,000-pound Universal Testing Machine in the Materials Lab.

Member of The Engineering College Magazines Associated
Chairman, John A. Henry, Univ. of Illinois, Urbana, Illinois
Publishers' Representative, Littell-Murray-Barnhill, Inc.
101 Park Ave., New York and 605 N. Michigan Ave., Chicago

Published monthly—October to May—by the Cornell Engineer, Inc., Lincoln Hall, Ithaca, N. Y. Edited by the undergraduates of the College of Engineering, Cornell University. Entered as second class matter at the Post Office at Ithaca, N. Y., under Section 103, Act of October 3, 1917.

Subscription per year: regular $2.00; with membership in the Cornell Society of Engineers $3.00 (See President's page); student $1.50; single copy $.25.

This issue: May, 1948.



JET
tion
thermo
gineeri
dents l
theless
modyn
an unc
underly
engines
courses
article
these f

The
gine is
obtains
atmosp
compre
bustion
from th
pansion
tion wi
product
One fun
the co
propelle
engine
rearwar
thrust t
dynami
engine.
tween t
air jet e
oxygen
while or
engine.

There
of class

A 46-fo
launching
Southwes
U.S. Arm
man V-2
mately 3,

A Thermodynamic Analysis of Jet Engines

By PROFESSORS CHARLES O. MACKEY
and NORMAN R. GAY

JET engines were not even mentioned in most of the courses in thermodynamics or heat-power engineering taken by engineering students before World War II. Nevertheless, practically all of the thermodynamic concepts necessary to an understanding of the principles underlying the performance of such engines were included in these courses. The general aim of this article is to show the application of these fundamentals.

The so-called thermal air jet engine is a propulsive device which obtains thrust by: (1) admission of atmospheric air into the engine, (2) compression of that air, (3) a combustion process that utilizes oxygen from this air to burn fuel, (4) expansion of the products of combustion with final expulsion of these products rearward at high velocity. One fundamental difference between the conventional aircraft engine-propeller combination and the jet engine is that the air accelerated rearward by a propeller to obtain thrust takes no part in the thermodynamic cycle of operation of the engine. The basic difference between the rocket and the thermal air jet engine is that both fuel and oxygen are carried in the rocket while only fuel is carried in the jet engine.

There are many different ways of classifying jet engines, but one simple classification divides these engines into three types: (1) ram-jet, (2) pulse-jet, (3) turbo-jet. The essential elements of the *ram-jet* engine are an inlet diffuser, a combustion chamber or combustor,

A 46-foot V-2 rocket rolls toward a launching site in the desert of the Southwest. Experimentation by the U.S. Army has revealed that the German V-2 had a top speed of approximately 3,600 miles per hour.
—*Courtesy General Electric Co.*

THE AUTHORS

Charles O. Mackey

Professor Charles O. Mackey, head of the new Heat-Power Engineering Department of the Sibley School of Mechanical Engineering, received his M.E. degree here in 1926. A member of the staff since 1924, he was made a full Professor in 1936. He has done considerable work as a consultant in air-conditioning and heat-power engineering. Formerly head of the Department of Mechanical Engineering Laboratory, Professor Mackey was made head of the new department when the two were combined in the Fall of 1947. He is a member of Tau Beta Pi, Phi Kappa Phi, Sigma Xi, and Atmos.

Norman R. Gay

Norman R. Gay, Assistant Professor of Heat-Power Engineering, received his B.S.M.E. at the University of Rochester and M.S. in M.E. here at Cornell. Professor Gay gained industrial experience by working for the Eastman Kodak Company. During the war he was a commissioned officer in the U.S. Navy. His publications at the Cornell University Engineering Experimental Station include "Radiant Heating and Cooling," and "The Effect of Jacket Temperature on Piston-Ring Wear of a Spark-Ignition Engine." Professor Gay is a member of Psi Upsilon, Phi Beta Kappa, and Atmos.

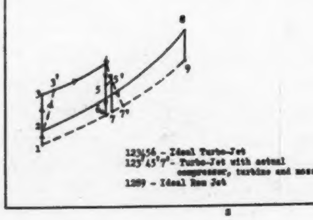
Air Speed mph	Air Speed fps u	Exit Velocity fps v_2	Ratio v_2/u	Fuel-Air Ratio M_0/M_1	Propulsion Efficiency
500	733	1100	1.5	0.02	0.8188
500	733	2200	3.0	0.02	0.5038
500	733	3300	4.5	0.02	0.3654
750	1100	1650	1.5	0.02	0.8185
750	1100	3300	3.0	0.02	0.5036
750	1100	4950	4.5	0.02	0.3653
500	733	2200	3.0	0.04	0.5073
500	733	2200	3.0	0	0.5000

Table 1. Propulsion Efficiency of Jet Reaction.

and an exit nozzle. In the inlet diffuser, the velocity of the air relative to the engine is reduced and the pressure of the air rises; in other words, there is a conversion of relative velocity head into pressure head. In the combustor, the fuel burns, and the products of combustion of the air and fuel leave the combustor at high temperature under conditions of steady flow. In the exit nozzle, these products of combustion expand to atmospheric pressure with a decrease in enthalpy and an increase in relative velocity. At no relative motion of the air and engine, there is no intake and compression of air and no thrust from a ram-jet engine. Other names given the ram-jet engine are the continuous-firing duct engine and the "athodyd" (the Aero-THermO-DYnamic Duct).

The pulse-jet engine may be described as an intermittent-firing duct engine. The essential elements of a pulse-jet engine are the inlet diffuser, inlet valve (under mechanical or automatic control), combustor, and exit nozzle. As used in the V-1 German Buzzbomb, the air was forced into the combustor by ram effect through shutters

Fig. 1. Temperature-entropy diagram for the ideal turbo-jet with imperfections, and the ideal ram-jet cycles.



opening against spring pressure at launching speed. Fuel was injected into this air stream in the combustor, ignited and burned; starting was effected with compressed air and electric ignition; in flight, the fuel was ignited by residual flame from combustion of previous charge. As the pressure increased during combustion, the front-end shutters were closed, and the products of combustion were expelled through a rear exit nozzle and tube; a suction was created in the combustor by this flow, and the shutters were reopened to start another cycle. The number of cycles per second was about forty—established by the natural resonance period for the long exit tube. Intermittent firing and exhaust results, of course, in intermittent thrust.

The elements of the turbo-jet engine are the inlet diffuser, compressor (centrifugal or axial flow), combustor, gas turbine, and exit nozzle. The turbine delivers just sufficient power to drive the compressor, so there is no net shaft power available. Air is compressed in the compressor, fuel ignites and burns in the combustor, the hot products of combustion expand through the turbine and exit nozzle. The first jet engines flown in this country were developments of Air Commodore Whittle's original design. The Bell P-59 Airacomet used the I-16 (1600 lb. thrust) turbo-jet engine built by the General Electric Company. The I-16 has a double entry centrifugal compressor with ten reverse-flow pipe combustors. The General Electric I-40 (4000 lb. thrust) is a later development in which the weight of the engine has been reduced from 0.53 lb. to 0.46 lb. per lb. of thrust. The fuel consumption of these engines is about 1.2 pounds per hour for each pound of thrust. Both General Electric and Westinghouse have built turbo-jet engines with axial flow compressors that have been used in Navy fighter planes. The General Electric TG-180 (Allison built) in the Navy Skystreak, which recently broke the world speed record, has 11 stages of compression, while the Westinghouse 19XB-2B has 10 stages. Generally, American gas turbines in turbo-jet engines have been single-stage machines with rotative speeds from 7600 to 36,000 rpm; some British turbines in turbo-jet engines have been multi-stage machines.

There are many possible combinations of aircraft engines where propeller thrust is augmented by jet thrust. For example, a gas turbine developing greater power than that required by the air compressor may be geared to a propeller, and the propeller thrust may be augmented by the products of combustion in the exit nozzle. Such a combination gives good overall performance at both low and high flight speeds.

The performance of the jet engine may be broken down into the performance of the jet in producing thrust and the thermal performance of the remaining equipment in producing the high exit velocity of the products of combustion.

Mechanics of the Jet Reaction

Assume a jet engine to be moving through stationary air at a speed of u ft. per sec. Air enters an air scoop with a velocity relative to the engine of v_1 ft. per sec. at the rate of M_1 lb. per sec; v_1 is equal in magnitude to u but opposite in direction, and will be assumed to be uniform over the section of the scoop. By energy transfers and transformations (thermodynamic processes), assume that the issuing gases have been given a uniform velocity relative to the engine across the discharge section of v_2 ft. per sec. If the engine burns completely M_0 lb. of fuel per second and uses all the air in the combustion process (no oxygen from any other source), the weight of the products of combustion leaving the nozzle per second is $(M_1 + M_0)$ pounds.

The jet engine has exerted a

force on the air and that part of the products of combustion having the same weight as the air of:

$$F_1 = \frac{M_1}{g}(v_2 - v_1) = \frac{M_1}{g}(v_2 - u) \quad \text{lb} \ldots\ldots\ldots\ldots \text{(1)}$$

This force is opposite to the direction of travel of the engine, and is found by application of the principle of impulse and momentum. The fuel carried by the engine had no initial velocity relative to the engine, but the portion of the products of combustion with weight equal to the fuel have acquired a velocity of v_2 relative to the engine. The force exerted upon the fuel and products of combustion of the same weight as the fuel is:

$$F_0 = \frac{M_0}{g}(v_2 - 0) = \frac{M_0}{g} v_2 \quad \text{lb} \ldots\ldots\ldots\ldots \text{(2)}$$

The total reaction force (thrust) that acts upon the jet engine in the direction of its motion is:

$$F_2 = F_1 + F_0 = \frac{M_1}{g}(v_2 - u) + \frac{M_0}{g} v_2 \quad \text{lb} \ldots\ldots\ldots\ldots \text{(3)}$$

For each pound of fuel burned per second, the thrust is:

$$\frac{F_2}{M_0} = \frac{1}{g}\left[\frac{M_1}{M_0}(v_2 - u) + v_2\right] \quad \text{lb sec/ lb} \ldots\ldots \text{(4)}$$

The *thrust horsepower* is:

$$P = \frac{F_2 u}{550} = \frac{M_1}{550g}\left[u v_2 - u^2 + \frac{M_0}{M_1} u v_2\right] \ldots\ldots\ldots\ldots \text{(5)}$$

The *minimum power* that must be supplied in the combination of thermodynamic processes that produce the exit relative velocity of v_2 ft. per second for $(M_1 + M_0)$ pounds per second of products of combustion is made up of: (1) the power required to increase the relative kinetic energy of M_0 lb. per second of products of combustion from O to $v_2^2/2g$; (2) the power required to increase the relative kinetic energy of M_1 lb. per second of products of combustion from $u^2/2g$ to $v_2^2/2g$.

This minimum horsepower that must be supplied in the thermodynamic processes is:

$$P_1 = \frac{M_1}{1100g}\left(v_2^2 - u^2 + \frac{M_0}{M_1} v_2^2\right) \ldots\ldots\ldots\ldots \text{(6)}$$

The *propulsion efficiency* may be defined as the ratio of the thrust horsepower to the minimum power that must be imparted to the exit fluid and is:

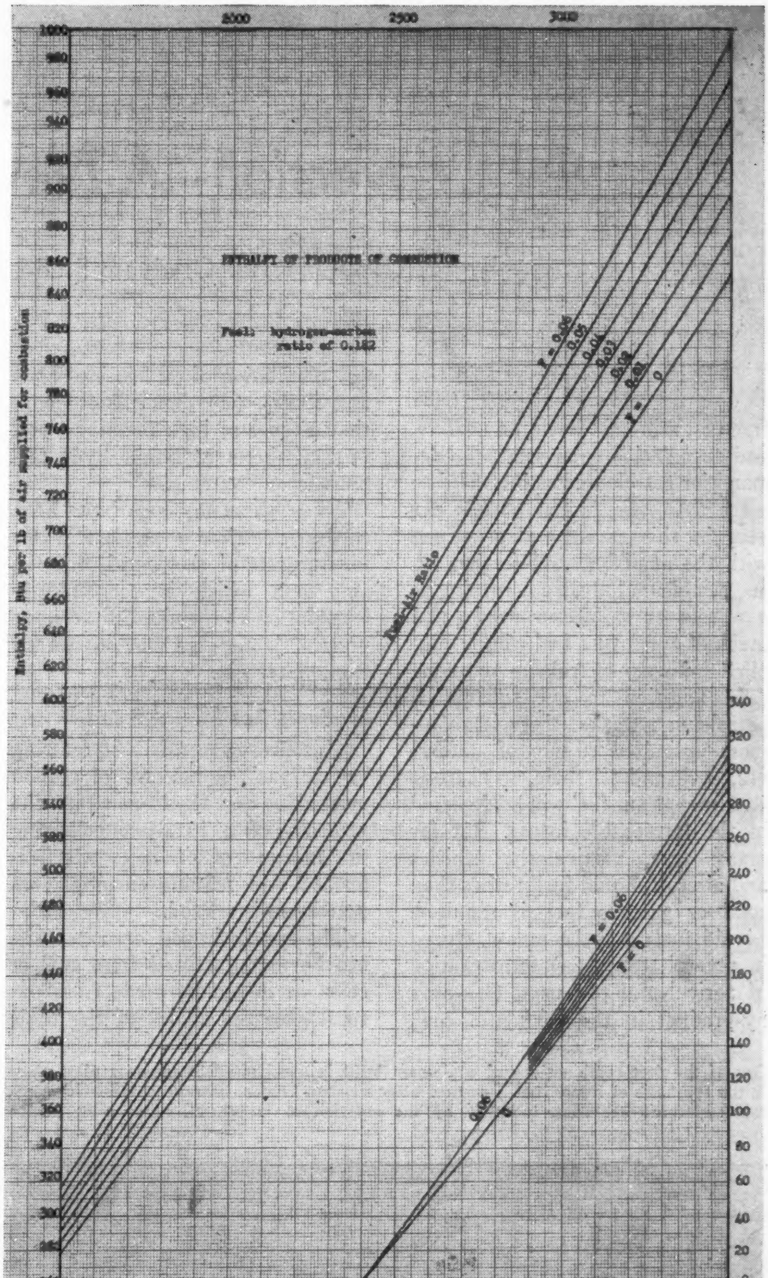


Fig. 2. The enthalpy of the products of combustion plotted against temperature, for various fuel-air ratios of the ideal turbo-jet engine. Kerosene is the fuel; no dissociation is assumed.

$$\eta_1 = 2u\left(\frac{v_2 - u + \frac{M_0}{M_1} v_2}{v_2^2 - u^2 + \frac{M_0}{M_1} v_2^2}\right) \ldots\ldots\ldots\ldots \text{(7)}$$

In general, the propulsion efficiency of the jet engine depends upon: (1) ratio of exit velocity of products of combustion to air speed; (2) air speed; (3) air-fuel mixture ratio. For very large values of the air-fuel ratio $(M_0/M_1 = O)$, the propulsion efficiency depends only upon the ratio of the exit velocity to air speed and is:

$$\eta_1 = \frac{2}{1 + \frac{v_2}{u}}$$

A few values of propulsion efficiency selected to show the effect

(*Continued on page 34*)

A NON-PETROLEUM
FUEL SOURCE

Fuel Conversion--A New Industry

By SAXE DOBRIN, Graduate Student, ChemE

WITH a steady increase in the production of aircraft, farm tractors, railroad diesels, oil heaters, and automotive equipment, the demand for petroleum has increased to more than two billion barrels per year in this country alone. Even with the availability of foreign oil, our petroleum industry is turning to new sources to fill our needs, and much of our future fuel will be supplied from non-petroleum sources.

In addition to our substantial petroleum reserves, there is an almost unlimited supply of natural gas, coal, and oil shale, so there is no fear that our fuel will be depleted in the foreseeable future. But for many uses, particularly vehicles and aircraft, liquid fuel, rather than solid or gaseous fuel, is required. Liquid fuels may be manufactured in several ways: (a) fermentation of agricultural products, (b) as a by-product in the coking of coal, (c) distillation of oil bearing sands and shales, (d) direct hydrogenation of coal at high pressures, and (e) synthesis of liquid hydrocarbons from "water gas."

All of these methods have been used at one time or another in different parts of the world, but the only one which is economically feasible in the United States, at present, is the last one—synthesis from water gas.

Synthesis Gas

This process consists of reacting "water gas", a mixture of carbon monoxide and hydrogen, in the presence of a catalyst, collecting the mixture of products which is formed and refining them just as petroleum is refined.

The synthesis gas, or water gas, can be manufactured from coal or coke, or it can be made from natural gas; the choice of the basic material depends upon its price and the cost of gasification or conversion.

When steam is blown through a red-hot bed of coke, synthesis gas is formed:

$$H_2O + C = H_2 + CO$$

The reaction is endothermic and the coke bed must be reheated periodically by burning part of the coke with air:

$$O_2\ (+ 4N_2) + C = CO_2\ (+ 4N_2)$$

The two reactions must be alternated or the nitrogen from the air will dilute the water gas. More recently, oxygen has been used instead of air, so that heating and gas generation can be done continuously without dilution by nitrogen.

Water gas may be produced by oxidation of natural gas as well as by steaming of hot coke. Since natural gas is predominantly methane, the chief reaction is:

$$CH_4 + \tfrac{1}{2}O_2 = CO + 2H_2$$

Here, too, oxygen is used, rather than air. The fuel conversion plants in the United States will use natural gas to take advantage of the present low prices from Texas and Kansas gas fields.

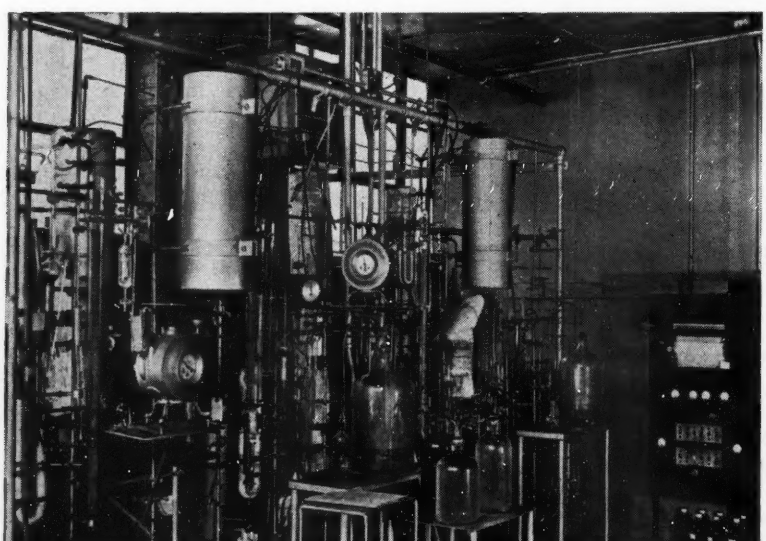
To provide the optimum mixture for hydrocarbon synthesis, the hydrogen content of the water gas is enriched by further reaction of part of the carbon monoxide with steam:

$$H_2O + CO = H_2 + CO_2$$

The CO_2 is removed by absorption in a solvent. Besides H_2 and CO, the synthesis gas will contain small amounts of inert CH_4, CO_2, and N_2.

Several variations of the process have been developed for the manufacture of hydrocarbons from water gas. The processes differ in the ratio of H_2 to CO in the gas, the type of catalyst used, the temperature

One of the first combinations of equipment built in the United States as a pilot plant in the synthesis of liquid fuel. Designed after Fischer-Tropsch installations in Germany, this apparatus has been followed by the erection of larger, all-metal pilot plants.
—Courtesy M. W. Kellogg Co.



and pressure of reaction, and the type of products produced. They are all variations of the process originally devised by Franz Fischer and Hans Tropsch and frequently the hydrocarbon synthesis process is referred to as the *Fischer-Tropsch* process.

Many reactions occur simultaneously in the catalytic reactor, some resulting in saturated hydrocarbons, others in unsaturated hydrocarbons. If a cobalt-type catalyst is used, straight-chain paraffins predominate, while with an iron catalyst, olefinic hydrocarbons are prominent. Valuable alcohols, ethers, ketones, and other oxygenated compounds are formed as well.

The products leaving the reactor are cooled and condensed, and uncondensed gases being recycled to the water gas generator or used as fuel. The hydrocarbon product is fractionated into a "liquefied gas" fraction, a gasoline fraction, a light distillate oil, and a small amount of wax. The oxygenated compounds, being soluble in water, are separated from the hydrocarbon product and recovered separately.

The catalysts which are most satisfactory for commercial synthesis are iron and cobalt, with small amounts of thorium, aluminum, or manganese added to increase their catalytic activity. Iron catalysts, though less active than cobalt catalysts, form more olefins and branched-chain hydrocarbons, and thus produce a gasoline with a higher octane number.

Operating Conditions

Temperatures and pressures vary widely among different processes which have been tried, ranging from 350 to 900 deg. F. and from 0 to 4000 lbs. per sq. inch. Pressures of 500 lbs per sq. in. or less are best suited to the manufacture of motor gasoline while higher pressures are better suited to waxes and heavy oils. Although the synthesis reaction can be carried out at atmospheric pressure, commercial operation is at 300 lbs. per sq. in., to decrease the size of equipment somewhat, and to obtain a better quality product.

The reaction process generates a great deal of heat—about 5000 Btu per lb. of product. Until the development of fluid catalysts, the removal of this heat was the major limitation of the capacity of a reactor.

German wartime synthetic gasoline plants were operated with "fixed bed" reactors in which the catalyst was packed in contact with large banks of cooling tubes. Because of poor thermal conductivity of the catalyst, heat removal was slow. The temperature of the catalyst could not be permitted to rise too high, or "coking" would occur, and the catalyst would be deactivated by carbon deposits. Because of the expensive construction of the reactors, and their limited capacity, the German plants were not economical.

An aerial view of a research laboratory and pilot plant in Tulsa, Oklahoma, for the developing of hydrocarbon synthesis and chemical refining processes. The buildings in the foreground house the pilot plant equipment.

—Courtesy Stanolind Oil and Gas Co.

American companies have solved the heat removal problem by making use of the fluid catalyst reactor originally developed for petroleum cracking. The "fluid catalyst," consisting of fine particles of solid catalyst, is suspended in the stream of synthesis gas. Inside the reactor, the catalyst bubbles and boils, just as though it were a liquid. Because of the violent agitation, the temperature is uniform, and the yield and quality of product can be easily controlled. A part of the catalyst is withdrawn continually and passed through a cooler where it gives up its heat before returning to the reactor. The heat is not wasted, but is used for steam generation to supply the rest of the plant with power.

The catalyst must be rugged enough to withstand the buffeting it receives, and for this purpose, a new iron catalyst was developed. The new catalyst is not only stronger than the cobalt-on-clay catalyst used by the Germans, but also is able to operate at higher temperatures, and give a better grade of motor gasoline.

One plant, to process 60,000,000 cu. ft. of natural gas per day, is

(*Continued on page* 32)

THE AUTHOR

Saxe Dobrin

Saxe Dobrin is a graduate student in the School of Chemical Engineering. He holds the Philco Fellowship and is studying properties of packaging materials which are used for frozen foods. Saxe was born and raised in Minneapolis. He attended the University of Minnesota and received the degree of Bachelor of Chemical Engineering in 1944. In 1944 and 1945 he was with the NDRC Rocket Division in Pittsburgh and in Cumberland, Maryland, where he designed, developed, and tested new types of rocket and jet take-off propellants. He is a member of Gamma Alpha, graduate fraternity, and Al-Djebar, chemical society.

**SUNSPOTS AID UNRAVELING
OF GEOMAGNETIC PHENOMENA**

Aurora and Its Terrestrial Effects

By CARL W. GARTLEIN, Ph.D. '29

Photographs by the Author

THE aurora polaris has been noted in historical records made at least 2000 years ago and must have excited the awe and wonder of man as long as he has lived in the austral and boreal regions of the earth. In the last two hundred years it has been the object of continuous scientific study. The causes of the aurora and its complex phenomena are worthy of study for their own sake, but they are of increasing interest because they may give clues in unraveling other complex phenomena of geomagnetism and of the ionosphere. All of these phenomena are now believed to be the varied manifestations in the earth's atmosphere of swarms of particles shot out from the sun.

The sun is a variable star whose proximity allows us to study it carefully. Though the total radiation varies only about 2%, many interesting changes occur on the sun's surface. Dark spots appear in two belts (latitudes 20° to 40°) and wax and wane in an 11 year cycle. Nearly all have magnetic fields, some as strong as 9000 oersteds. The spots are not uniformly distributed over the sunspot latitudes, but appear in higher latitudes early in each cycle and gradually approach the lower limit at the end of the cycle. Certain longitudes seem to contain the active spot regions for many months and then others become more important. The spots may be unipolar, bipolar, or complex according to the number and kind of magnetic "poles." The complex spots nearly always are accompanied by geomagnetic manifestations when they are near the center of the disk. The sunspot latitudes rotate with a period of about 27 days. Since magnetic storms and auroras tend to recur after an interval of 27 days, a solar effect seems quite clear.

Spectacular Eruptions

Regions of the sun near spots are often covered by clouds of calcium and hydrogen which are observed by the spectrohelioscope. Spectacular eruptions of hydrogen and other gases often move outward with very high velocity, 1000 km. per second. The sudden radio fadeout, Dellinger effect, occurs in step with these flares. Around most of the sun is the corona composed of light from highly ionized atoms. The corona changes gradually with few visible effects in the course of several days.

As fundamental data on solar characteristics the sunspots are counted, and prominences are described by type and intensity. The data on particle emission by the sun cannot be derived directly and are inferred from the phenomena on the earth.

The magnetic field of the earth changes by small amounts in intensity and direction in a systematic fashion, but at times the magnetic elements are erratically disturbed by what are called "mag-

THE AUTHOR

Dr. Carl W. Gartlein

Dr. Carl Witz Gartlein, director of the National Geographic Society-Cornell University Study of Aurora since 1938, is one of the outstanding authorities on aurora borealis in the world. Born in Connersville, Indiana in 1902, Dr. Gartlein studied at De Pauw University as a Rector Scholar and received his A.B. in 1924. He came to Cornell where he received his Ph.D. in 1929 for work in spectroscopy. Since then he has served the Department of Physics in several capacities. First an assistant, then an instructor, he later became Curator of the Physics Department. At present, he holds the title of Superintendent of Technical Service Personnel. Dr. Gartlein is the author of a recent article concerning his study of the aurora appearing in the November, 1947 National Geographic Magazine.

A bundle of rays appearing against the Eastern horizon. The angle that the rays make with the skyline is equal to the angle of dip of the Earth's magnetic field.

netic storms." Even then the intensity changes only a few percent and the direction changes only a few degrees. These magnetic disturbances are largely produced by changes in the electric currents which circulate in the upper atmosphere of the earth. The total current passing around the northern belt may exceed one million amperes and may change at the rate of 100,000 amperes per minute. These currents induce earth currents. The effect of earth currents on the electric telegraph and telephone has been well known, and the last sunspot cycle gave two instances of interference on electric power lines.

On March 24, 1940 at 11:48 a.m. and later, several power line disturbances occurred in the northeastern United States. There were voltage dips up to 10% for short times; differential relays on transformer banks tripped, and some transformer fuses were blown. There were large reactive power surges which could have been produced by direct currents in the power lines causing transformer saturation. In most cases these power lines were connected to ground at widely separated points, and the line was in parallel with ground to carry a large fraction of the earth currents. Similar events occurred on September 18-19, 1941. These are described in the July, 1940 *Edison Electric Institute Bulletin,* and the November, 1941 *Scientific Monthly.*

Long distance radio communication depends on wave reflection or refraction at the Kennelly-Heaviside layers. This ionosphere region about the earth is a region where the electron density increases as the height increases. It has been shown that electrons are almost entirely responsible for the signal reflection.

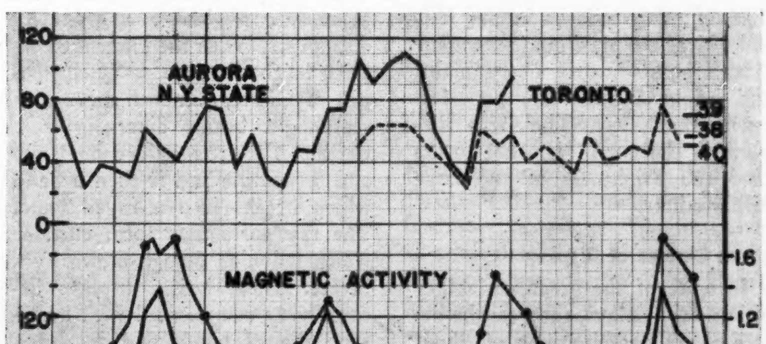
The ionosphere has been found to consist of three layers E, F_1, and F_2, in the daytime, and of two, E and F, at night. The layers are somewhat diffuse on the lower side, but of such density that the heights can be definitely determined as 100, 210, and 300 km. for daytime near the equator, and 110 and 200 km. at night. These heights vary with season and time in the sunspot cycle and thus show a solar relation. The annual mean ion density in the F_2 region bears a linear relation to the sunspot number, though daily values do not bear this relation. This indicates that some fundamental emission changes occur on the sun which we cannot measure otherwise, and that sunspots appear to be the result of something more fundamental. The changes in these layers during magnetic disturbance are very complicated and only a few general statements can be given. Usually the ion density decreases somewhat, the layers rise and become diffuse and then cloudy. The entire ionosphere seems to expand and the total ion numbers may increase though the layer density decreases. Usually absorption of signals increases and fading is very bad. Occasionally an intense E layer develops which is of high ion concentration. This layer prevents high frequencies from reaching the F layer, if it is present, and greatly interferes with long distance communication, but gives unusual range to the signals above 40 megacycles. This sporadic intense E ionization is usually present at night during the aurora.

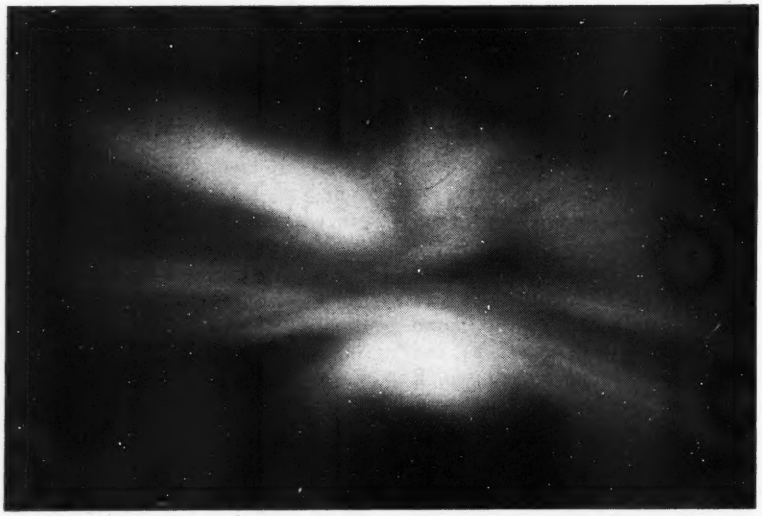
Minor Aurora Form Present

The aurora is present in some minor form much more frequently than is suspected by most city dwellers who live in the regions of bright lights and listen to strong local radio stations. Records kept by the academics of New York State from 1830 to 1865 seem to indicate at least 20 auroras per year, and often very many more. From May 3, 1944, to May 1, 1945, some form of aurora was noted on 75 nights at stations in the Lakes regions of the United States. About half of these were of the faint diffuse glow type.

The aurora occurs most frequently in a zone extending from Northern Norway, across lower Hudson Bay, Point Barrow, and Alaska, to Northern Siberia. Either north or south of this, the fre-

Chart showing the relation between the cycles of sunspots, magnetic disturbances, and aurora, for the years 1830 to 1874. The peak of the aurora cycle lags slightly behind that of the sunspot cycle.





Corona which appeared on September 18, 1941. This is formed by rayed bands through the magnetic zenith, but perspective makes the parallel rays appear to converge.

qency is less. This zone does not follow a geographic latitude parallel but does approximately follow geomagnetic latitude (roughly circular around Etah, Greenland). Thus we find our longitude 76° W. about the most favorable in the northern hemisphere for viewing the aurora; that is more auroras are seen in our longitude than in Europe at the same geographic latitude. The most famous aurora research has been conducted in southern Norway where the aurora frequency is only a little better than in Montreal. The number of auroras per year follows the sunspot cycle approximately, though the peak is after the sunspot peak. Auroras and magnetic storms occur more frequently in the equinoctial months than in other months in our latitude. Near the maximum zone some aurora occurs nearly every night, and bright auroras are more frequent than here. The large displays in the north seem not to exceed the brightness of the large displays here.

Three Classes of Display

In spite of the great variability of auroral displays, they can be described as combinations of about twelve descriptive forms. These twelve are grouped in three classes: ray forms, homogeneous or non-ray forms, and pulsating forms. The ray forms are the ray, rayed arc and band, drapery, and corona. The non-ray forms are glow, diffuse surface, homogeneous arc, and band. The pulsating forms of arc and surface (or clouds) and flames complete the list.

These forms have a tendency to appear in rather definite sequences which we will discuss in some hypothetical auroras. The smallest aurora consists only of a glow, a diffuse veil of light extending upward from the northern horizon and fading out gradually above. Often an arc, part of a circle, rises from the north. It is usually sharply bounded below and thus has a definite northern boundary. The usual height of these is 90-110 km. above the earth. Presently the glow fades, the arc brightens, and may break into isolated parts or into diffuse surfaces (cloudlike) which fade again into a glow, and gradually disappears. When the lower arc border is bright the arc usually changes to a rayed arc, a smooth curve with searchlight beams diverging from the top. The arc may become wavy and serpentine and is then a band which breaks into a rayed band. The ray parts may form curtains which move as though blown by a breeze. These larger displays become very complicated with horseshoe shaped bands and draperies. As they move south of the zenith the rays converge to a point forming a corona. This convergence is a perspective effect since all the rays are closely parallel. Measurements show that ray forms are higher than arc forms. They run from 120 to 175 km. in height and sometimes to 1000 km. when the upper atmosphere is sunlit. The corona center is the direction of the pointing of the upper end of the dip needle. Another relation is that arcs lie along the geomagnetic latitude parallels and have their highest point on the geomagnetic meridian.

Pulsating Forms Appear

The pulsating forms appear just after the peak of the display and may take the forms of an arc which emits faint arcs which travel upward rapidly. The most exciting form is the flame where waves of light pass up ray forms to give the appearance of flames. The pulsating surface seems to be a brightening and fading diffuse surface.

Of course the combinations are varied and striking. Five arcs have been seen at one time at Ithaca. Unusual forms are the high arc, 200 km. in place of 100 km., which is widely separated from other aurora. Regularly spaced rays are very rare as are certain types of pulsating forms.

The height of the aurora has been determined from simultaneous photographs taken at widely separated stations. This has been done in Norway extensively. The National Geographic Society-Cornell University Study has made many such pairs of photographs, though they have not been measured. The lowest height ever measured was about 60 km., and the average lower border is 100 to 110 km., while the usual top of rays is about 175 km. It should be noted that the heights correspond to the region between the E and F radio layers, while the higher auroras, 600 to 1000 km., are in the region where scattered radio reflections occur during intense ionosphere storms.

The aurora study was begun at Cornell to provide data on lower latitude auroras. Large groups of volunteer observers have sent reports on their visual observations. Several United States Weather Bureau stations have acted as observers. The data from four observers have been analyzed for the years 1938-1941, while Ithaca data have been studied for 5 years.

The magnetic K figure is a good

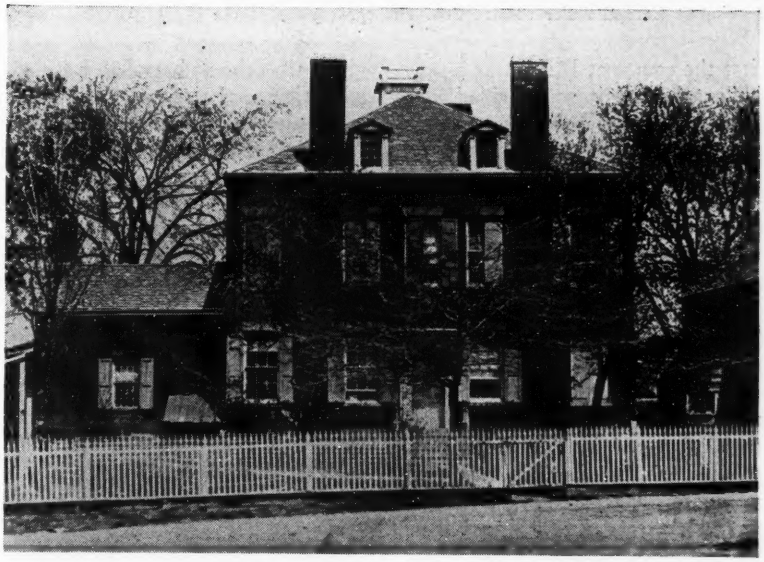
(*Concluded on page 26*)

The Early Growth of Engineering in America

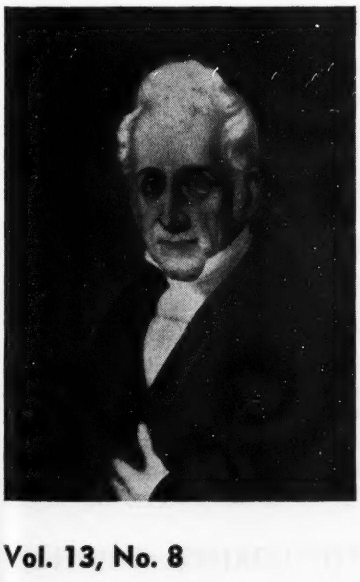
By ROBERT J. BURNS, EE '50

ENGINEERING, as applied to construction, is as old as history itself. The pyramids, the temples of ancient Greece, and the aqueducts and roads of Rome are familiar examples of the skill of the early builders. The term "engineering" probably originated in Europe during the Middle Ages, and at first it applied only to the construction of fortifications and projects of a military nature. From this developed civil engineering, denoting any such work which was non-military in character. Until the "Industrial Age" had gotten well under way, civil and military engineering were the only recognized branches of the profession.

At the time of the Revolution, American industries were suffering from a lack of skilled workers, since prior to the war the English had discouraged all forms of manufacturing in the colonies. After the war, England again tried to crush the young industries in America by selling her goods here at lower prices than the local manufacturers could afford to charge. In an attempt to combat this situation and to secure and consolidate industrial independence, societies were formed for the promotion of the useful arts, premiums were offered from the state treasuries for inventions and improved methods, and skilled foreign artisans were invited to settle here. Out of these efforts came the first significant accomplishments of American engineering.



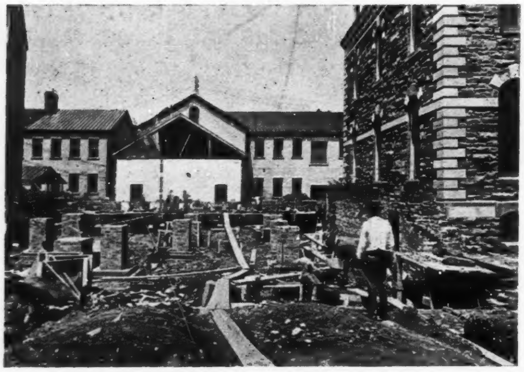
The building in Troy, N. Y. which housed the first classes of Rensselaer Polytechnic Institute. This school, the first of its kind in the United States, was founded in 1824.
—Courtesy R.P.I.

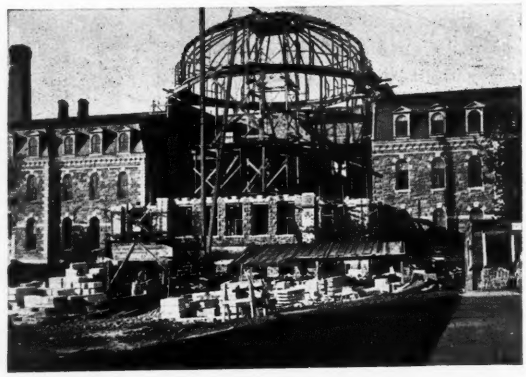


Stephen Van Rensselaer, who established the first true engineering school in America upon the advice of Amos Eaton, geologist and pioneer in technological education.
—Courtesy R.P.I.

Eli Whitney's invention of the cotton gin, Robert Fulton's success with the steam boat, and other inventions of the time pointed the way toward a self-sufficient American industry. At about the same time several canals were constructed in this country. The inventions were made by Americans with no formal engineering training, while the canals were supervised by foreign-trained civil engineers. The first great achievement of American civil engineering was the Erie Canal, built between 1817 and 1825 by three self-trained Americans, James Geddes, Benjamin Wright, and Charles Brodhead. However, with the exception of the West Point Military Academy, the young nation still had no recognized institutions for training engineers.

In 1824 Rensselaer Polytechnic Institute was founded, and for a quarter of a century thereafter R.P.I. and West Point answered the country's need for civil engineers with scientific training. At





The familiar dome of the Sibley School of Mechanical Engineering at Cornell under construction. The cornerstone of the original Sibley College was laid in 1870, and the east wing and dome were added several years later.

first the course at R.P.I. was a year in length, and it was divided into three terms, but before long it was lengthened to three years. For the first five years R.P.I. employed a method of instruction which was new in America and unique in elementary education. Observation of actual industrial processes was made the subject of class discussion, and laboratory problems which led to general principles by inductive reasoning were employed. Although this system was successful, it had to be dropped in 1829 because it was to expensive for the school's inadequate finances. In place of this method, a plan was adopted from the French technical schools, where the fundamental sciences were taught first, and then their application in industrial processes. From the time of its introduction at R.P.I., it has been and still is the basic principle of engineering education in America.

It was not until 1847 that Harvard, Yale, and the University of Michigan added engineering courses to their curricula. Apparently engineering was considered a threat to the academic traditions of these institutions, and it was only after a difficult struggle that it became a firmly established and accepted part of American higher education. From the very beginning, however, those who advocated training on a college level for the engineer were in general agreement on the need and functions of such training. The ultimate objective of even the earliest engineering schools was increased industrial production, to be accomplished through systematic teaching of applied science. Moreover, the schools hoped to raise engineering to the status of a learned and respected profession, and to foster scientific research.

Professional Growth

Engineering as a profession grew concurrently with the schools, and the latter were an important factor in shaping the profession. When R.P.I. was founded, it initiated its program without the guidance of professional standards, for at that time there was no recognized engineering profession. An unsuccessful attempt was made to found a national civil engineering society in 1839, but it was not until 1852 that the American Society of Civil Engineers was finally established. The other early societies were the American Institute of Mining Engineers, founded in 1872, the American Society of Mechanical Engineers, in 1883, and the American Institute of Electrical Engineers, in 1884.

The U. S. census report for 1850 listed only 512 engineers, all of them civil. Sixty years later, the 1910 census showed 14,514 mechanical engineers, 6,930 mining engineers, 52,033 civil engineers and surveyors, and 135,519 electricians and electrical engineers. Because of the general listings, it is impossible to tell the exact number of professional engineers at that time. It is estimated that only about 80,000 out of the total 208,966 could have qualified for membership in the above societies. The effect of the growth of the schools on the profession is shown by the fact that in 1870 one out of every eight or nine engineers was a college graduate, while by 1918 the proportion had risen to one out of two.

However, with the accumulation of more and more technical knowledge, the problem of training men adequately to fill industry's needs has grown more difficult of solution. By the time such colleges as M.I.T. and Cornell were founded with the help of the Morrill Act, mechanical engineering had come to be recognized as a separate and equally important field, rather than merely a branch of civil engineering. Around 1887, under the general heading civil engineering, M.I.T. offered courses in civil, railroad, and topographical engineering. Under mechanical engineering were listed marine, locomotive, and mill engineering. Cornell was one of the pioneers in teaching electrical engineering, instituting courses in 1883, and establishing the School of Electrical Engineering in 1919. Since the turn of the century, engineering has expanded to embrace fields which are too numerous to mention, and which the early advocates of college training could scarcely have foreseen.

Only 40% Graduated on Time

As far back as 1918, the colleges were plagued with a badly congested curriculum. The Mann Report on engineering education, prepared that year for the Carnegie Foundation, supplied statistics which show the similarity between conditions then and now, and which may be a source of consolation to students struggling through engineering to-

(*Concluded on page* 30)

Alumni News

Charles G. Renold, M.E. '06, has been knighted. He is chairman of the board of Renold Coventry Chain Company, Ltd., of England.

Edward R. Stapley, C.E. '14, M.C.E. '30, previously the acting dean, has been appointed dean of the division of engineering of Oklahoma A. & M. College. "We have five other advanced degree Cornellians on our engineering staff," he reports.

S. Everett Hunkin, C.E. '17, was elected president of the Hunkin-Conkey Construction Company, Cleveland.

Henry C. Givan, B.Chem '26, after having served with the Equitable Gas Company of Pittsburgh since 1926, recently resigned his post of sales promotion manager to become manager of the refrigeration department of the Pittsburgh Products Company. While with Equitable, Givan served as engineer of tests, heating sales engineer, supervisor of refrigeration and radio sales, and supervisor of trade development. In World War II he spent his four years in the Army Air Forces as training officer in the Western Flying Training Command, contracting officer in the contract termination branch of the AAF, and base executive officer in the Pacific Theatre.

Edgar H. Bleckwell, M.E. '33, has been appointed manufacturing superintendent of a new nylon plant which DuPont is building in Chattanooga, Tenn.

Herbert C. Bostwick, B.S. in A.E. '35, and **Robert B. Roe, E.E. '39,** are both engaged in an important segment of aviation research at Sperry Gyroscope Company at Great Neck, L. I. As flight director for the company, Bostwick supervises a flight base, a fleet of aircraft, and a group of skilled pilots and technicians. Roe serves as flight operations manager and is second in command at the base at MacArthur Field, L. I. He joined Sperry shortly after his graduation from Cornell and, after a time in the service department, transferred to flight research. More than a year ago he received training to fly P-80 jet fighters, thus becoming one of the first civilians cleared by the Air Force and trained to fly these speedy fighters.

Henry C. Givan

Harvey McChesney, Jr., C.E. '39, recently became administrative assistant to the head of the architectural planning and plant maintenance department of the Brookhaven National Laboratory, Upton, N. Y., which is engaged in atomic energy research for the Atomic Energy Commission.

James W. Falk, B.E.E. '45, has joined the patent department of Bell Telephone Laboratories in New York City. There are six other Cornellians among the seventy members of the department (about twice as many as from any other institution): **Stanley B. Kent '11, Cordelia Mattice '14, Guy T. Morris '14, John C. Morris '26, Sherman N. Turner '41,** and **David H. Wilson, Jr. '46.**

Deceased

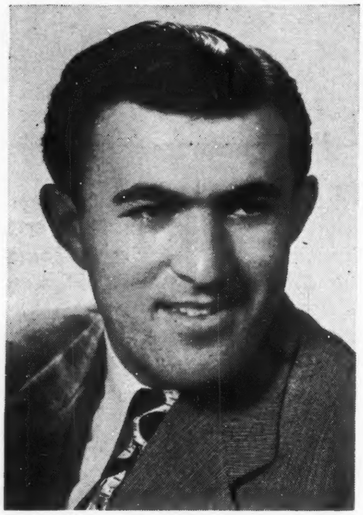
George Stuart Laing, E.E. '01, former president of the West India Oil Company, died on March 6, 1948. He had been a vice-president and governor of the American Chamber of Commerce of Argentina, and a director of the American Chamber of Commerce of Santiago, Chile. He served as a field artillery lieutenant in France in World War I and as a Red Cross executive overseas in World War II.

Frank Nehemiah Waterman, M.E.(E.E.) '89, was a consultant to many electric and radio corporations until he retired in 1939. He handled many early patent cases for General Electric and Radio Corporation of America. An ardent mountain climber, he was a member of the American, Swiss, and Canadian Alpine Clubs.

William Holliday Rose, M.E. (E.E) '97, on December 6, 1947. An engineering consultant and inventor, he had taken out more than 100 patents.

Douglas Franklin Stevens, M.E. '07, for the last eight years a research associate with the Illinois State Geographical Survey. He was a former president of the Illinois Clay Manufacturing Association and was an organizer and chairman of the structural clay products division of the American Ceramic Society. He had been general manager of the Acme Brick Company for thirty years.

PROMINENT



Bill

William Kaplan, CE

Just the mentioning of a baseball game is all that is needed to arouse Bill Kaplan. In other seasons football or basketball would be just as effective. Being an avid fan of the Washington "Senators" during the summer, the "Redskins" in the fall and the "Caps" during the winter, it was natural that Bill would become sports editor of the *Cornellian* after he came to Cornell. But sports do not consume all of Bill's time. He is also a member of the Willard Straight Forum Committee, Tau Beta Pi, Chi Epsilon, and Tau Epsilon Phi.

A native of Washington, D. C., Bill was valedictorian of his class when he graduated from McKinley Technical High School in 1942. He always liked science and math and decided Civil Engineering was his field. He then entered Purdue University with a four year scholarship, but his training was soon interrupted when Bill joined the Army Air Forces. Bill became a navigator with the Eighth Air Force in England. There he flew on the first England to Russia shuttle bombing mission, flew on D-day, and had six missions over Berlin under his belt. On his twenty-sixth mission Bill's B-17 was shot down, and Bill, the sole survivor of his crew, became a prisoner of war until ten months later when the Russians arrived to free him.

Once more a civilian, Bill decided he preferred an Engineering school closer to his home. Cornell was his choice. Bill, who now stands at the top of his class in the School of Civil Engineering; doesn't think Cornell is any tougher than Purdue. Looking forward to graduation in June, Bill hopes to enter into construction work with a contractor, but his plans are still quite flexible and will depend upon the opportunities being presented when he leaves Cornell.

Philip E. Silberberg, CE

An ability to get things done quietly and efficiently tempered by a dry sense of humor characterizes Phil Silberberg, a senior CE of varied interests and accomplishments. During his eight and one-half terms at Cornell, Phil has served in just about every editorial capacity on the CORNELL ENGINEER save editor-in-chief, in addition to adding his distinctive touch to several other campus activities.

Phil entered Cornell in March, 1944, following graduation from Boys' High School in New York City. At the end of his first semester, he picked up a State Scholarship that was retroactive to the time that he entered Cornell.

His climb to the top was interrupted here by the United States Army which saw fit to call Private Philip Silberberg into training in April, 1946. This detour from his main goal had some value for Phil as a very interesting adjunct to his education. During the year he served in the Army, he saw such places as Panama, Hawaii, and the Philippines.

Phil

Other activities that have attracted Phil's attention have been WVBR, for which he announces regular news broadcasts and request shows, CURW, and the Cornell Student Branch of the ASCE, whose official publication, the Lincoln Log, he helped to re-found and edit in the spring of 1946. Phil pledged Tau Epsilon Phi in his first term and has been an active member ever since.

Plans for the future include an interest in doing grad work, preferably in engineering law. Whatever the future holds, however, Phil may well survey his Cornell career with satisfaction as he says, "That's baseball," catching his fingers when closing the books for the last time.

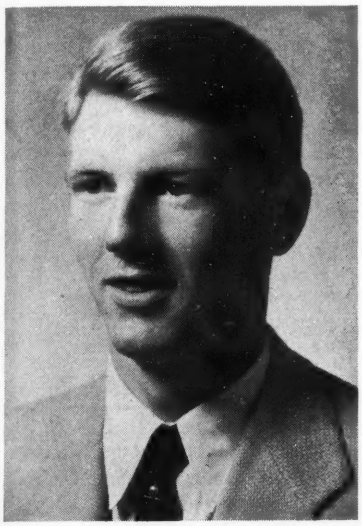
Charles von Wrangell, ME

This spring the Cornell crews are again plowing the blue waters of Lake Cayuga preparing for the Poughkeepsie Regatta and the Olympic trials in Philadelphia. Filling the No. 7 oar spot in the varsity shell again this year is Chuck von Wrangell, senior Mechanical Engineer.

Chuck came to Cornell in 1943 after being graduated from Culver Military Academy. He chose the Mechanical Engineering School "at the suggestion of his father"; and in spite of the heavy schedules of engineering he has found time for many outside activities which speak for his abounding energy.

Crew is perhaps Chuck's strongest interest and his record in this speaks for itself. He has been a mainstay of Cornell crew all four of his years here on the hill. When he was back at Culver he was captain of an undefeated crew, and in

'46 he was the Commodore of the victorious Cornell crew that won the International Regatta. Last year he was selected as the seven man on the mythical All-American crew. Von has also been president of the crew club, but crew is just one of his accomplishments. Chuck's red hair and friendly smile became well known his first year at Cornell when he was on the Willard Straight freshman committee and in Pershing Rifles of which he was captain.



Chuck

Then his studies were interrupted by a call from the Army Air Corps where he served until his discharge in 1945. But Cornell was not to be forgotten and neither was von Wrangell, for he returned to Ithaca and resumed an active part in student affairs. As a counsellor at Frosh camp he gave potential ME's the low-down on mechanics and calculus prelims, and talked a good many into coming out for crew. After serving on the staff of the Cornell Desk Book, he became editor of last year's issue. His latest interest has been cheerleading, and this year saw him head of the squad that put on such a good performance during the football and basketball season. During his junior year he was elected to Aleph Semach and Chuck is now treasurer of Quill and Dagger, and a member of Atmos and Wagonwheels. As a member of Alpha Delta Phi he often amuses the brothers with a session on the guitar, which he plays very well.

Chuck's plans for the future are not yet definite. His studies during his senior year have taken a philosophical bend and he is now applying for admission to Oxford or Cambridge "to gain more knowledge." Wherever he does go, however, we suspect that he will continue to do a great job.

Hugh L. Myers, ChemE

Hugh

Arriving at Cornell fresh from Tunkhannock, Pa., High School on July 4th, 1944, Hugh plunged right into the grim business of becoming a chemical engineer, and with but a few interruptions he has been at it ever since. Attracted to Cornell by Dusty's fine reputation and a full tuition McMullen Regional Scholarship, Hugh set out to make the most of his stay here; as a member of the Big Red Band he tried to work up some college spirit in the V-12s at the football games, and after his election to the editorial board of the ENGINEER he helped tide that worthy publication over part of the uncertain war period. Hugh was admitted to membership at Cayuga Lodge shortly after he arrived here, and in his third term was elected vice-president of the Cayuga Student Residence Association.

But of course his civilian bliss could not last forever. At the end of his third term, while only 17 years old, Hugh enlisted in the Navy, and was promptly sent to Franklin & Marshall College, and then to Bucknell, as a member of the V-5 program. While at college under the Navy, Hugh was able to take many subjects which were required for a ChemE degree. At Bucknell he was Navy editor of the yearbook, *L'Agenda,* which, he says, was about the only work he did there all term. In April of 1946, however, he was pulled out of college and sent to Memphis for preflight training. But the war was long since over, and after a few weeks, orders came through for the disbandment of the V-5 units. Hugh was separated at Bainbridge, and remained on inactive duty until his final discharge, which didn't come through until December, 1947.

Hugh has been back at Cornell since October '46, and is approaching the end of the long climb to B.Chem.E. His scholastic record is enviable; he was elected to Tau Beta Pi in January '47, is a charter member of Pros-Ops, and has been a consistent dean's-lister. A loyal affiliate of the American Institute of Chemical Engineers, Hugh is intensely interested in everything that concerns his chosen profession. This year you'll find him peddling slide rules and log-log paper for E. J. Morris almost any afternoon, but he still has time to serve at Cayuga Lodge on the board of directors, and as chairman of the membership committee.

After June—what? For Hugh the immediate future is fairly well settled; he'll marry the girl who waits for him back home, and then take up a job at the Marcus Hook refinery of the Sun Oil Company. And this sincere, hard-working, likeable Cornellian should have little trouble forging ahead from there.

NEWS FROM

Honorary Elections

Tau Beta Pi

Thirty-four members of the Electrical, Chemical, Mechanical, and Civil Engineering Schools, and the College of Architecture were elected to Tau Beta Pi on April 8. A banquet for the new members was held following a short pledge period. Elected from the College of Chemical Engineering were Dave Benedict, Joseph Jewitt, Fred Siefke, Vic Stibolt, and Dave White. The seven members elected from the Electrical Engineering School were Donald Oberg, Eugene Galton, Warren Messner, Paul Robeson, Jr., John Seider, Roger Thayer, and Ted Yaffe. Harold Andrews, Ben Sze, Wallace Clarke, Harvey Bumgardner, Ted Fedkew, Warren Higgins, Robert Harnett, George Kosc, and Silvio Volpe were chosen from the Mechanical Engineering School. Elected from the Civil Engineering School were Willard Bliss, Paul Dickinson, Roger Chapman, Hugh Chapin, Volney Plumb, James Spencer, and Russell Meyer. And the new members from the Architecture College are William Doan, Richard Schreiber, Russell Strecker, Gordon Johnson, David McCandless, and Daniel Wiegner.

Pyramid; Rod and Bob

Pyramid and Rod and Bob, honorary Civil Engineering societies recently held elections. The new members elected to Pyramid were Melvin Bennett, Chauncey Burtch, Joe Dawson, Bob Mattie, Vince Moore, Henry Murphy, Joe Nolan, Volney Plumb, Mark Shriver, and John Ten Hagen. The initiation banquet was held with Rod and Bob on Thursday, March 11. The new members of Rod and Bob include two members of the faculty, Professor B. K. Hough and Ray Hodge. The undergraduate initiates were Dick Colle, Chuck Bauerlein, Jack Jaso, Bob Crandall, Joe Schrauth, Al West, Phil Marshall, and Bill Wade.

Rod and Bob also elected Bob McKinless as president, Tom Baker to the position of Secretary-Treasurer, and Alexander Borsani as the social chairman. This year is the fiftieth anniversary of Rod and Bob which makes it one of Cornell's oldest honorary societies. A banquet was held at the Lehigh Valley Hotel on May 2 to commemorate the occasion.

Atmos

Eleven engineers of the class of forty-nine were elected to Atmos, honorary mechanical engineering society. The new members are Eugene Hoffman, Charles Read, James Sliger, Fred Hoerle, Robert Rath, Robert House, William Behr, Harris Cooperman, Frank Walker, Leif Arnesen, and Kenneth Murray. The initiation banquet was held at the Old Landmark on March 19.

Pi Omicron

Pi Omicron initiated four new members February 27 in Olin Hall. The initiates were Leonilda Altman, EP '51, Eleanor Egan, ChemE '51, Claire Johnson, EE '49, and Marilyn Thatcher, ME '49. A dinner for the new members was held in Willard Straight Hall following the elections. Mrs. Amy Spear '48 was elected vice-president, filling the vacancy left by the graduation of Shirly Ann Ogren, M.E., in February.

Inspection Trips

Vacation for eighth term chemical engineers consisted of little more than a change of scene over the recent spring recess due to the usual spring inspection trip. For five days, from March 29 to April 2, the group, consisting of seventy-one students and four faculty members, Prof. C. C. Winding and Asst. Profs. J. C. Smith, R. L. Von Berg, and H. W. Wiegandt, toured chemical engineering installations in western New York, Ontario, and Pennsylvania.

Leaving Olin Hall at 8:30 AM on March 29, the group left in two chartered buses for first-hand observation of, among other points of interest, the nitration of cellulose at the Eastman Kodak Co. in Rochester, N. Y., where they spent the first night at the Hotel Powers. The next three days, basing their operations on the Hotel Lafayette in Buffalo, N. Y., the group visited the following industries in that area: the Lapp Insulator Co., the Buflovak Equipment Co., the Rayon Division of E. I. duPont deNemours and Co., the Hooker Electric Co., the Ontario Paper Co., and the International Nickel Co.

On April 2 they left Buffalo and,

C.E. ALUMNI:

Your Reunion Breakfast is to be held June 12

On Saturday, June 12, 1948, the Faculty of the School of Civil Engineering, will be host at the breakfast to be tendered to the Civil Engineering Alumni who return to Ithaca for the reunion.

The breakfast will be held in the basement of Lincoln Hall from 7:30 to 10:30 A.M., EDST.

It is hoped that the resumption of this social function will prove as attractive to the Alumni as it did until 1942, when war conditions made it necessary to discontinue holding the breakfast. All returning C.E. Alumni are invited and urged to plan to attend the breakfast and to make the occasion a real "Old Home" affair.

THE COLLEGE

after stopping at the Donner-Hanna Coke Corp. in Lackawanna, N. Y., and the Bethlehem Steel Co., arrived back at Olin Hall late that evening, weary but somewhat the wiser for this intensive first-hand contact with the industry to which they aspire.

Composing an integral part of the Plant Inspection course required of all chemical engineers, the purpose of this annual trip arranged for the Junior class is to acquaint the students with actual industrial installations of the smaller chemical engineering equipment which has occupied them for many hours during the term in that course of courses, Unit Operations, and to introduce them to many unit operations and unit processes of which many of them have only read in their texts.

CE's Visit New York City

Not to be outdone, the Junior class in civil engineering scheduled its inspection trip the first week of May. Led by Prof. H. M. Gifft the student group visited civil engineering projects in the vicinity of New York City, including the Idlewilde Airport, the Brooklyn-Battery Tunnel, and the George Washington Bridge, as well as stopping en route at the Bethlehem Steel plant in Bethlehem, Pa.

Co-op Plan Enlarged

The Sibley School of Mechanical Engineering and the College of Electrical Engineering have enlarged the cooperative plan in conjunction with the General Electric Company and the Philco Radio Corporation. The men that have been accepted for the new program will work at these plants this summer, and return to Cornell for the fall semester. They will then return to their field work during the spring semester, and make up the work missed during the spring term by attending school on a full semester basis during the summer of '49. The program was made possible by Professor Strong of the College of Electrical Engineering, who conducted the negotiations with these companies.

Faculty Bowling Results

The close of the weekly winter meetings of the University Bowling League found active ninety faculty members of the Electrical, Mechanical, and Civil Engineering Schools.

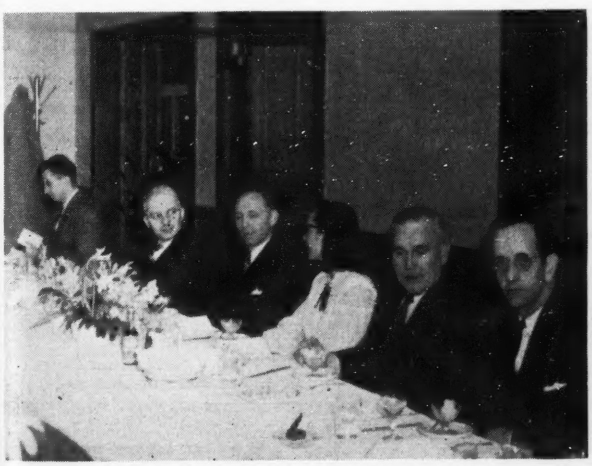
In the Sibley Bowling League the high individual average score for the year was won by Professor Purcell, with the high series being taken by Professor Ehrhart. The high single individual scoring was won by D. E. Bacon. The Materials team had the greatest number of points at the end of the season, and the mechanics department team won the high series score.

In the final results of the Lincoln league Professor R. Y. Thatcher had the highest individual average for the season and also the high-series. Professor Belcher won the high game scoring. The Old Timers team walked away with the team honors in all three—the high average, game, and series. In a Sweepstakes held on March 25, Professor H. T. Jenkins was the winner.

Electrical Engineering's Franklin Bowling league shows the following results. Professor Erickson had the highest average in the final tally, while G. J. Watt won the individual score honors. In the team results the Watts ended up with the most points.

THE ANNUAL *CORNELL ENGINEER* BANQUET

was held on Friday, March 5, at the Lehigh Valley Hotel. Seated at the Speaker's Table below are, l. to r., Ben-Ami Lipetz, M.E. '48, former Managing Editor; Dr. C. R. Burrows, Director of the School of Electrical Engineering; Guest Speaker, Dr. Lloyd P. Smith, Director of the Department of Engineering Physics and Chairman of the Physics Department; Miss Billie P. Carter, ChemE '49, retiring Editor-in-Chief; Professor Carl Crandall, Director of the School of Civil Engineering; and Edward A. Reed, Senior Technical Instructor of the General Motors Die Engineering Program, who is the author of the article, "Manufacturing Progress Through Process Planning," which appeared in the November issue of the ENGINEER. On the right, Miss Billie Carter, retiring Editor-in-Chief, congratulates Carl P. Irwin, CE '49, newly-elected Editor-in-Chief, as he and his concomitantly elected editors assumed their positions effective with last month's ENGINEER.



Cornell Society of Engineers

107 EAST 48TH STREET 1947-1948 NEW YORK 17, N. Y.

CARL F. OSTERGREN, *President* ....175 Broadway, New York 7, N. Y.

CREED W. FULTON, *Executive Vice-President*
The Cambridge, Alden Park, Philadelphia 44, Pa.

PAUL O. REYNEAU, *Secretary-Treasurer and Representative, Cornell University Placement Service,* 107 East 48th St., New York 17, N. Y.

IRA L. CRAIG, *Vice-President* ....1000 Chestnut St., Philadelphia, Pa.

KARL J. NELSON, *Recording Secretary* ....321 North Avenue East, Cranford, N. J.

WILLIAM F. ZIMMERMAN, *Vice-President* ....103 Archer Road, Syracuse, N. Y.

KARL J. NELSON, *Vice-President* ....321 North Avenue East, Cranford, N. J.

GEORGE C. BRAINARD, *Vice-President* ....1200 Babbitt Rd., Cleveland, Ohio

LINTON HART, *Vice-President* ....418 New Center Bldg., Detroit 2, Mich.

"The objects of this Society are to promote the welfare of the College of Engineering at Cornell University, its graduates and former students and to establish a closer relationship between the college and the alumni."

Carl F. Ostergren

President's Message

Effort to find a significant message to offer in my last use of this page having given me no brilliant ideas, some general commentary arising from the experiences of a year in this administrative sort of job may be of interest and possibly helpful.

The alumni interest in carrying on the great tradition of Cornell engineering training is truly important. I find this to be generally agreed upon, and suggest to succeeding officers of the Society that if they will find the useful assignments, capable hands can be found to carry them out.

Cornell's engineering reputation has not been lowered in the last twenty-five or thirty years, taken as a whole. Some other schools have been coming up in that period, several earning new prestige and others reclaiming what they formerly had. M.I.T. seems to rank first in general opinion, and more power to her. There is no reason to feel, however, that Cornell need take second place to any school.

There appears to be a degree of undergraduate dissatisfaction about the class contacts of faculty with students, even though the ratio of teachers to pupils has been kept well above average by the administration. The need of maintaining the quality as well as quantity of faculty is certainly uppermost in the minds of the college officers, but there is a suggestion present that greater personal interest, with the initiative on the part of the professors and instructors, could be promoted. At the same time, the Dean and Directors are of course concerned about an improved research position. It goes to show they have their problems. From my own point of view, I can only assert that they have shown every indication of welcoming suggestions offered by former engineering students.

The willingness of men like Creed W. Fulton, Vice-President of Creswell Iron Works of Philadelphia, and William Littlewood, engineering Vice-President of American Air Lines, to accept nomination as President and Executve Vice-President, respectively, of the Society is proof of its vitality. Both have a great record in their professional field and as active Cornell alumni. The Nominating Committee, headed by Robert B. Lea, Vice-President of Sperry, is to be complimented.

Incidentally, why all this Vice-President business? One of these fellows ought to take the Vice out of their titles pretty soon.

In these comments, I must recognize the invaluable services of Paul O. Reyneau, the Secretary-Treasurer of the Society. I'm glad also to report him as a fine person to those of you who don't happen to know him.

The *Cornell Engineer* has improved since the days when I had an assistant editor's job on the Sibley Journal. There have been real problems of financial relations between the magazine and the Society, which Robert M. Smith has handled with ability and, I hope, understanding from the Society's standpoint, and the editors have displayed both a firm and a cooperative attitude.

With all good wishes to the readers of this page, professionally and in their assistance to the Cornell Engineering Schools.

CARL F. OSTERGREN

Proposed Informal Lounge

BY DONALD E. READ, ME '50

During recent years, there has been much talk about the fact that the Engineering College at Cornell is not a unified and spirited body. There is a need in a professional school for a place where students and faculty can shed the strain of school and become friends, rather than always student and professor in a classroom. At the present time there is no such place available here, where students and faculty can gather in a relaxed atmosphere, come to know each other, and become a unified and spirited group with common interests.

The proposed lounge would serve as a gathering place for any engineering group desiring to use it. It would be extremely desirable as a place where students could relax and enjoy a cigarette without violating the University ruling of no smoking in the buildings. It would relieve congestion in the Sibley library and provide an excellent place for current reading material to be used. Also, it could provide a permanent place for the records and meetings of such engineering societies as Tau Beta Pi, Kappa Tau Chi, and Atmos. Lastly, it would provide impetus for school spirit, both among students and between students and faculty.

The first major obstacle to be surmounted was the finding of a space suitable and available in an overcrowded school. This past winter, Dean Hollister granted the room in the south-west corner of the basement of Sibley Dome for the lounge. This room has been found well suited for the lounge, since it is not in use at present, is a large, well lighted and heated room, and is easily accessable from within the building and has a direct entrance from outside.

Mr. Creed Fulton, Executive Vice-President of the Cornell Society of Engineers, was kind enough, in behalf of his organization, to give his time for the inspection of the room. His suggestions for the conversion are coupled with those of the sponsoring societies and are presented below.

The room presents a relatively easy job in conversion, but the sum of approximately three thousand dollars ($3000), or its equivalent in materials and labor, will be needed to convert and completely furnish the room as a comfortable lounge. The reconditioning of the room consists of the following jobs:

1. Floor
   a. Filler to even out irregularities.
   b. Linoleum or cork covering.
2. Walls and Ceiling
   a. Paint (light green, two-toned) for the walls.
   b. Acoustic material covering for ceiling.
3. Enclosure of Steam Controls
   a. "Transite" board, or its equivalent.
   b. Lumber for the framework.
4. Furnishings
   a. Additional lighting fixtures, including standing lamps.
   b. Furniture to comfortably equip the room.
   c. Radio
   d. Coca-Cola and cigarette dispensing machines.

Outside Aid Needed

It should be noted that the major portion of this expenditure is to go for furnishings. These furnishings can be moved to the new Engineering building, when it is completed, for use in a similar lounge. An estimated figure of two thousand dollars ($2000) was arrived at for the furnishing of a presentable lounge.

The major difficulty before us now is the financing of the project. It is hoped that this can be done through contributions by alumni for without their help, there is little hope for final completion of the project.

The Editor's COLUMN

Wanted— An Honor System

Is cheating on exams a problem in College of Engineering at Cornell? If the results of a recent survey by Tau Beta Pi are to be believed, it is. Of the two hundred and seventy-six students returning questionnaires, approximately 65% were in favor of a uniform honor system for the College of Engineering. This shows that many students feel that something should be done about the existing situation . . . a situation which is unlike many at Cornell in that the student themselves can do something about it—if they only will.

At the present time the only engineering honor code at Cornell is in the School of Civil Engineering. It has been in operation for some 16 years, and although it is far from perfect, it is generally felt that it has been successful. A student elected committee administers it, but depends upon reports of violations from the students themselves. It is here that an honor system either succeeds or fails, for if the students are not willing to turn in violators the system cannot function properly. It is an understandable reaction not to "squeal" on a fellow student, but it is also understandable, to the thinking student, that the cheater is penalizing the rest of the class, and receiving the benefits of a good grade without the work that such a grade should entail.

The students in the School of Civil Engineering organized their own honor system. If, as the Tau Beta Pi survey indicates, the other schools want an honor system, it is up to the student leaders in those schools, but let them not forget that unless a majority of the students are willing to abide by both of the provisions for a successful honor code and report violators as well as maintain their own integrity, the system is doomed from the start.

Out of Phase

By HERBERT F. SPIRER, EP '51

How to Change a Course in the ME School, or a Boiler-Time Story for Junior Engineers.

. . . As told by S. J. Vladmir Sitzfleisch (who should have known better) to the columnist.

After two horrible weeks in section 45 of External Combustion Engine (ECE 124098) I decided that it was time for a change of section. It wasn't that the instructor, Mr. A. P. Athetic, was exactly incompetent, but he had developed the annoying habit of sitting with his back to the class and eating bananas while lecturing. He must have known his subject well, because no one knew what he was talking about.

Threw Used Banana Skins

He was especially down on me. He would throw the used banana skins at me. Sometimes he would empty a box of chalk over my head. Said that I didn't look attentive enough. Slowly I began to get the impression that I was a victim of erudite discrimination.

The first out and out act of oppression came one blissful rainy Saturday morning. He had just spent three minutes deriving Newton's Third Law using double eliptic integrals and said, "Are there any questions?", and chattered on. I interrupted him. Yes, I squeaked, I have a question. "What?!" he screamed, the long scar on his right cheek growing livid with rage. He stamped over to me, clicked his heels together, removed his gloves, one finger at a time, and hit me in the face with the gloves. "Sit down, sir," he growled, "Sit down, and shut up!" From that day forward I realized that I was unwanted.

ECE 124098 was held at ten a.m. Section 69 was at twelve noon with a different instructor. Ha, I thought, if I could switch my twelve psych class to the afternoon section I could find safety in the noon ECE section 69. I would be free!

Wednesday afternoon I decided to skip lunch and make the necessary arrangements for transfer. I really wouldn't miss too much, Home Ec was featuring minced cloven lamb's hoofs, fricasse of hydrangia patties with pigeon's liver sauce, with crushed tomatoes, and the line at the Straight reached down into the mud pits near the temporary dormitories.

Reverently I walked through the great marble corridors of Goldwin Smith with the hope of finding my psych prof., Prof. Meggerhoffen. Then I saw him standing next to Romulus and the Wolf surrounded by a small group of chattering little art students, most of whom were dressed in the height of fashion, white buck shoes six sizes too large. I looked down at my own acid perforated (Chem 105) brogans, and moved forward humbly.

"Sir," I ventured, "If you would be so kindly as to consider the possibility of changing my psych section from—"Why son," interrupted the great man, smiling and patting me fondly on the head, "We're here to give you an education. How can you get an education if you aren't happy? Why, if *you* think you can get more out of another section, we think so too . . . Be a fine school where the faculty didn't look out for the students welfare, wouldn't it . . . hyuch, hyuch hyuch . . ." He chuckled and poked me playfully in the ribs with a copy of Roget's Thesaurus. I laughed hysterically.

"And don't worry about the forms," he said, "I'll just change your name from one section to the other. Nothing to it if I do it."

I tripped gayly out in the pouring rain. My heart was filled with benevolence. My Cornell. My school. My best friend. A home away from home. Good old school. Alma Mater. Loves every one of her kiddies. So what if our living quarters are one step above a footlocker. At least we get educated properly. What support. My school, faithful to the end.

Cheerful as a boy scout I bounced into the office of the ECE director. Miss Inter Mittent, assistant to the associate secretary to the director's third helper came to port arms and pinned me against the wall with a quill pen. "Just where do you think you are going?"

"Heh, heh," I countered cleverly, "I want to see the boss." "Ah Youth," she said, "Full of hope. Well, draw up an orange crate and sit down. By the way, what did you want?" I explained my situation and brought her to tears. Then I waited. And waited, and waited, and waited. Twilight came, and the bells sang out with the Evening Song. Then Miss Inter Mittent turned to me and laughed, "Oh, my, isn't that funny . . . the Director won't be in until tomorrow." I crawled home to my slab to spend a night in sleepless agony.

Perched on Window

The next morning I perched on the window outside the director's office. I saw him enter, open the Sun and study Dick Tracy avidly. He grinned and I thought I saw a flash of kindness in his eye. I leaped into the room. Before he could speak I shouted out my sad story. I explained how simple the whole thing was. All that I needed was a slip to admit me to the twelve

(*Concluded on page* 28)

Aurora Effects

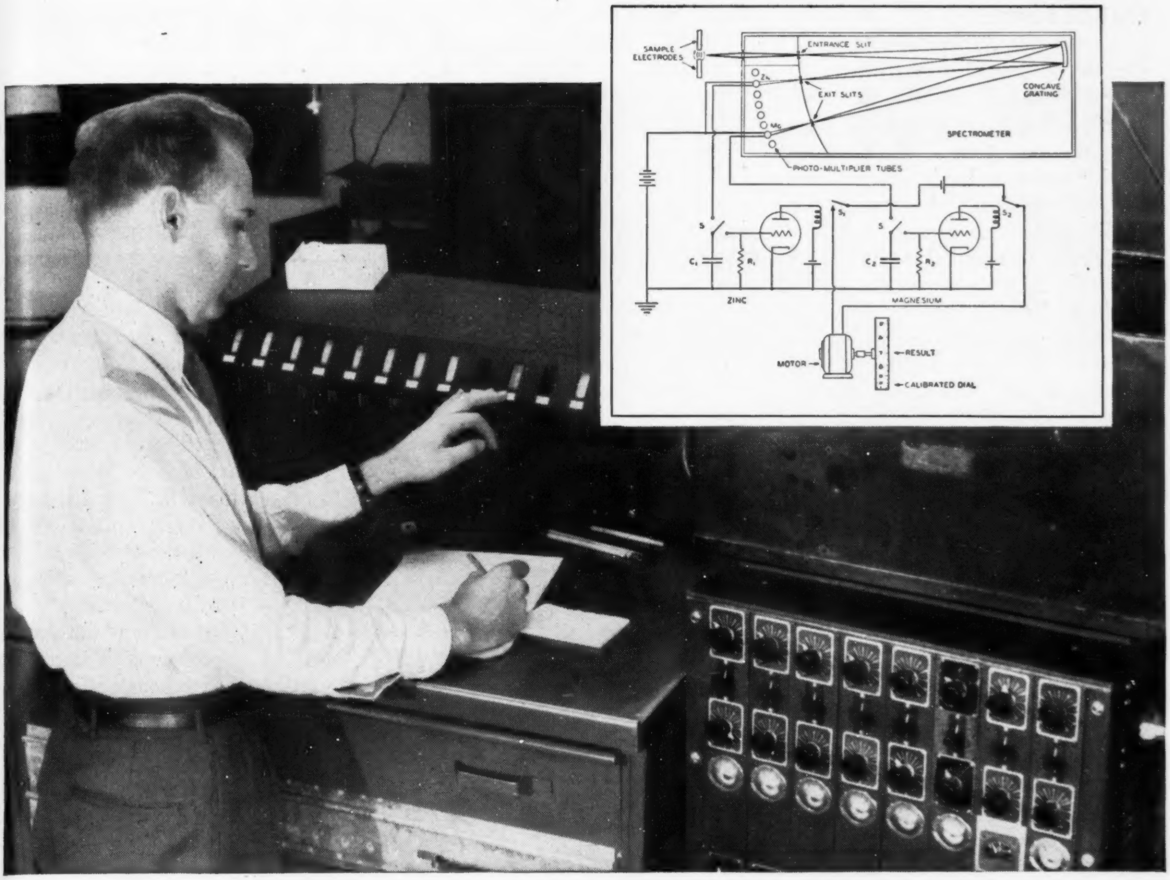
(*Continued from page* 14)

measure of magnetic storminess. The correlation coefficient between the aurora and magnetic data is 0.82. This indicates a definite relation between these data; in fact this relation is one of the closest between magnetic disturbance and any other phenomenon.

The relation of auroral phenomena to other events has been made difficult by the lack of quantitative data on the aurora. We have built several spectrographs and a photoelectric recorder to give quantitative data. A large spectrograph with 4 inch prisms and F/1.65 lens by Bausch and Lomb has given several fine spectrograms which show the presence of atomic and ionic nitrogen lines, in addition to the well known forbidden oxygen lines and molecular nitrogen bands. Two spectrographs are run as patrol instruments and are shut off by clockwork before dawn. One of these, with an F/0.73 lens built by Eastman Kodak and kindly loaned to Cornell, has been most successful in showing the presence of faint aurora while the writer was sleeping, and will detect even moderate auroras in cloudy weather. A photoelectric recorder uses a sector disk, photomultiplier phototube, A.C. amplifier, rectifier and recorder. This has been operated for several years.

These records show several types of aurora development, the slow changing glow, the slow change in brightness of the arc and some peaked records which show a sudden increase in brightness and a slow decay. This sudden increase is coincident with a sudden decrease in the horizontal component of the magnetic field and promises to give even more interesting information. This is one of our most important problems. This brightness increase occurs at the time when the arc breaks into rays. We plan to study this in several light wave-lengths and have built new photoelectric equipment which will largely eliminate the effect of moonlight. A large searchlight has been acquired to use as a light collector to enable us to study changes in brightness of a small part of the aurora.

The present sunspot cycle has risen rapidly to even higher values than the last cycle, which was quite unusual. We are now near or have just passed the peak of the cycle, so we expect unusual auroral and magnetic activity during the next two years.



The Dow-developed Spectrometer with simplified schematic diagram showing its essential features.

Out of Phase

(*Continued from page 24*)

o'clock ECE section and it was all over. I finished, and he frowned.

"Now look, young man, we'll ignore the fact that I don't customarily make a habit of speaking to students. Do you realize the bookkeeping this change will entail? Why to make this change for you will take eight secretaries six weeks of feverish activity. Suppose I were to let you change and it got around? Every student in the school would want to change courses and sections. And mind you, not for any purpose, but just to change. I know you students, always trying to find some way to mess us up—"

"But the Arts school changed it like there was nothing to it."

"Arts, Smarts, do you think we are running this school for you? Come here."He grabbed me by the collar and dragged me into the third subbasement, a monstrous room the size of Barton Hall. "Do you see those stacks of paper? Know what they are?"

"No," I replied looking about at thousands of bundles of printed forms stacked on every side.

"Well, they are applications for admission to our school for next Fall. You think we need you? Like a hole in the head. How did you get here anyway, a legacy? Here we break our backs letting you in, giving the finest tailor-made engineering education you could get anywhere, and you have the nerve to criticise one of our instructors. If we throw you out we can get ten replacements tomorrow. Students, fooey!" he threw me into a corner near twelve thousand applications from Kansas, and walked off mumbling unprintables.

When I got home that night I found some official mail. From the University I learn't that I had been dropped from my six-hour course for cutting the morning lab. And a ten dollar bill from the ECE department for use of one orange crate. A notice from Residential Halls that the maid complained because I hadn't made my bed before leaving the room.

And my six week marks,—25 in ECE 124098, and three incompletes. But the coup de grace was a reprimand from the Counselor of Students . . . My behavior in ECE class on a certain Saturday had been so obnoxious that it was only under the greatest compulsion, including two raises, that Mr. A. P. Athletic had been induced to remain at Cornell. My school. Alma Mater.

Please forward my mail to the Oswego School of Nursery Culture and Fine Art. There I have found peace. I was the only applicant for entrance this fall. The instructors speak to the class. Tuition cannot be raised without consent of the student. Slide rules are *verboten*, and the words "rigorous, trivial, or obnoxiously evident" may not be used by instructors. Three room apartments with heat and water for every student. And there are ninety-two women to every man. One at a time, boys . . .

Growth of Engineering

(*Continued from page 16*)

day. For example, Mann stated that few students succeeded in keeping up to grade without spending much less than fifty hours a week on their work. Furthermore, from a count made for twenty representative engineering schools, including Cornell, it was found that less than 40% of all freshmen graduated in the allotted time. However, this was an improvement over the early days of the schools, when the elimination was about 75%, and even 91% in some cases. The improvement up to 1918 was attributed to the increasing efficiency of the secondary schools.

An interesting fact to note from the Mann Report is that most of the elimination took place in the first two years, before the students had progressed to actual engineering courses. Morever, of the 40% who graduated on time, half just "squeezed by" in physics, calculus, and mechanics. Ratings of some of these graduates by the companies which subsequently employed them showed little correlation with their college marks, however. Apparently, these observations are just as valid today.

Heavy Course Burden

In 1867, students were carrying only four or five courses at one time, and the percentage of time spent on true engineering work was relatively low. The only technical subjects listed in an M.I.T. program for 1867 were drawing, mechanical engineering, machinery and motors, and stereotomy. Fifty years later, the requirements of the profession had risen so much that most students carried from eight to thirteen courses at the same time.

The average relative precentages of time spent on the three main fields of instruction at M.I.T. and Illinois in 1867 were:

Languages and humanities—27%
Mathematics and science—32%
Drawing and engineering—41%

In 1914, the figures, compiled as an average value for twenty colleges, were:

Languages and humanities—19%
Mathematics and science—29%
Drawing and engineering—52%

The percentage of work in the last category varied widely in different schools around the time of the first World War. At Northwestern it was only 25%, while Cornell required 70% and Michigan College of Mines 85%. Likewise, the language requirements ranged from zero at Cornell and a few other schools to 18% at Yale and Virginia Polytechnic Institute. Overall, the trend was clearly toward decreasing the time devoted to the humanities in order to make room for the fast increasing field of technical knowledge.

By lengthening their programs and decreasing the non-technical and non-scientific content, the schools have managed to keep abreast of the requirements thus far. How the years to come will alter the relationship between the student and the college, and between the colleges and industry, is a matter which only the economists and sociologists can pretend to predict.

Fuel Conversion

(*Continued from page* 11)

now being built in Brownsville, Texas, and will be in operation shortly. Another, to process 100,000,000 cu. ft. per day, is soon to be built in western Kansas.

Compared to the 5,000,000 barrels of crude petroleum which are processed each day, the 6000 barrel per day outputs of the first two synthetic plants will be small, so that the introduction of this process will not upset the petroleum industry overnight. The effect on the chemical industry, however, will be much more pronounced, for along with each 6000 barrels of fuel, some 400,000 pounds of various alcohols, aldehydes, acids, and ketones will be produced. The availability of large amounts of these chemicals will be a stimulus for the manufacture of many new products which were formerly not economically possible.

The oxygen for oxidation of the natural gas will be supplied from bulk oxygen plants, with capacities of 50,000,000 cu. ft. per day, far larger than any oxygen plants built before. The use of oxygen is made economical by the availability of excess power from the heat of the synthesis reaction. In the oxygen plants, heat recovery is important. The cooling of incoming air will be done with high capacity intermittent recuperators, instead of the tubular heat exchangers which were used in earlier oxygen plants. When the air is sufficiently cooled, it is liquefied, and fractionated into oxygen and nitrogen. The outgoing gases are reheated in the same heat recuperators. Small amounts of incoming air and outgoing oxygen intermingle on each cycle, so that the oxygen is not pure, but the small amount of nitrogen can be tolerated by the synthesis process.

The fuel conversion process is important as a new source of alcohols, aldehydes, acids, ethers, and ketones, as well as fuel. By varying the process it is also possible to make waxes, aromatic chemicals, and even edible fats and oils. Though the industry is in its infancy, its development is certainly one of the major advances of this decade.

Jet Engines

(*Continued from page 9*)

of these variables are given in Table 1.

Gas	A	B	C	D
CO_2	0.344	$2.38\,(10)^{-5}$	$-\,3.17\,(10)^{-9}$	-3.60
CO	0.156	$6.87\,(10)^{-5}$	$-\,8.82\,(10)^{-9}$	1.35
H_2O	0.261	$14.6\,(10)^{-5}$	$-11.2\,(10)^{-9}$	2.53
N_2	0.168	$5.93\,(10)^{-5}$	$-\,7.20\,(10)^{-9}$	1.19
O_2	0.260	$1.65\,(10)^{-5}$	$-\,1.50\,(10)^{-9}$	-1.13

Table 2. Specific Heats of Gases at Constant Pressure (zero pressure).

Thermal Performance

The thermodynamic processes in the cycle of operation of the jet engine are: (1) compression of air; (2) burning of fuel and heating of products of combustion; (3) expansion of products of combustion. Only the steady flow processes will be discussed—first for the turbo-jet engine and next for the ram-jet engine.

A temperature-entropy diagram for the open cycle of an ideal turbo-jet engine is shown in Fig. 1. Process 1-2 occurs in an ideal inlet diffuser, where velocity head of the incoming air is converted into enthalpy increase with no loss of head. Process 2-3 occurs in the ideal compressor and is an isentropic rise in pressure of the air. Process 3-4 is the process of burning of fuel at constant pressure in the ideal combustor. Process 4-5 is an isentropic expansion of the products of combustion in the ideal gas turbine which drives the compressor, and process 5-6 is an isentropic expansion of these products in the ideal nozzle.

The *thermal efficiency* of the engine is found by dividing the *minimum* rate at which energy must be supplied to change the relative velocity of M_1 lb. of air per sec. from u to v_6 and the relative velocity of M_0 lb. of fuel per sec. from O to v_6, by the *actual* rate at which energy is supplied.

In the case of the turbo-jet engine, it will always be assumed that the work delivered by the gas turbine is just sufficient to drive the air compressor. With either the turbo-jet engine or the ram-jet engine, then, there is assumed to be no net supply of energy except from the burning of the fuel.

The thermal efficiency of the turbo-jet engine, with the cycle of operation shown in Fig. 1, is:

$$\eta_2 = \frac{v_6^2 - u^2 + F v_6^2}{50000FQ} \qquad (8)$$

where v_6 is the exit or jet velocity of the products of combustion, ft. per second; u is the air speed of the jet plane, ft. per second; F equals the fuel-air ratio or (M_0/M_1); and Q is the higher heating value of the fuel at constant pressure.

The *overall efficiency* of the jet engine, as a propulsion device, is defined as the ratio of the thrust

(*Continued on page 36*)

Jet Engines

(*Continued from page* 34)

power to the rate at which energy is supplied to operate the engine, or:

$$\eta_3 = \eta_1 \eta_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

It is the purpose of the thermodynamic analysis that follows to determine the three efficiencies: propulsion, thermal, and overall for different assumed conditions of operation of turbo-jet and ram-jet engines.

Specific Heats

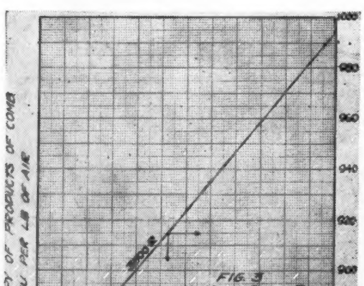
The specific heats of many gases based upon spectroscopic data have been presented over wide ranges of pressure and temperature by Ellenwood, Kulik, and Gay in Bulletin No. 30 of the Cornell University Engineering Experiment Station.

In the thermodynamic analysis of this article, the effect of pressure upon the specific heats of gases will be ignored, because low pressures are involved in the cycles studied. The effect of temperature upon specific heats will be included, however, in the analysis.

Empirical equations of good accuracy up to an absolute temperature of 4000R have been fitted to the specific heats of the gases at constant zero pressure. These equations are of the form:

$$c \text{ (const. p)} = A + BT + CT^2 + \frac{D}{\sqrt{T}} \text{ Btu/ lb F.} \quad (10)$$

Fig. 3. Relation between the enthalpy of products of combustion and the fuel-air ratio, for temperatures of 2000R and 3500R.



Values of the constants for several gases are given in Table 2.

Examples of Thermodynamic Calculations

In all of the examples, the fuel used is assumed to have a hydrogen-carbon ratio of N=0.182, a hydrogen-fuel ratio of M=0.154, and a higher heating value at constant pressure of the liquid fuel of 20,000 Btu per lb. at 520R. These are the properties of kerosene.

In each case, the air supplied for combustion is assumed to be a mixture of oxygen, 23.2 per cent by weight, and nitrogen, 76.8 per cent by weight.

The chart of Fig. 2 has been prepared to show the enthalpy of the products of combustion per pound of air supplied for this fuel at different temperatures for various fuel-air ratios, F. The enthalpy of each gas has been assigned a zero value at 400R. No dissociation has been assumed; the constituents of the products of combustion and the gas constant of the products of combustion are shown in Table 3.

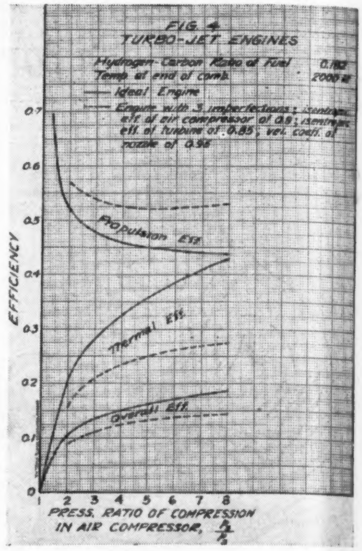


Fig. 4. Showing the effect of the pressure ratio of compression in the air compressor on the propulsion, thermal, and overall efficiencies of turbo-jet engines.

h_0—C=18,600 Btu per lb. of fuel.

Ideal Turbo-Jet Engine

The thermodynamic performance of the ideal turbo-jet engine has been calculated for one air speed,

Fuel-Air Ratio F	Weight of Products of Combustion lb. per lb. of air CO_2	H_2O	O_2	N_2	Gas Constant of Prod. of Comb., R ft. lb./lb. F
0	0	0	0.2320	0.7680	53.57
0.01	0.0310	0.0138	0.1972	0.7680	53.62
0.02	0.0620	0.0275	0.1625	0.7680	53.67
0.03	0.0930	0.0413	0.1277	0.7680	53.72
0.04	0.1241	0.0550	0.0929	0.7680	53.77
0.05	0.1551	0.0688	0.0581	0.7680	53.83
0.06	0.1861	0.0826	0.0233	0.7680	53.88
0.0667	0.2069	0.0918	0	0.7680	53.91

Table 3. Products of Combustion of Fuel with Hydrogen-Carbon Ratio of N=0.182. The maximum fuel-air ratio for complete combustion is 0.0667.

For the combustion process, the sum of the enthalpy of the fuel, h_0, and the chemical energy of the fuel, C, is found from the following energy equation based upon the chemically correct mixture ratio (F equal to 0.0667) and Q of 20,000 Btu per lb. for the liquid fuel at 520R:

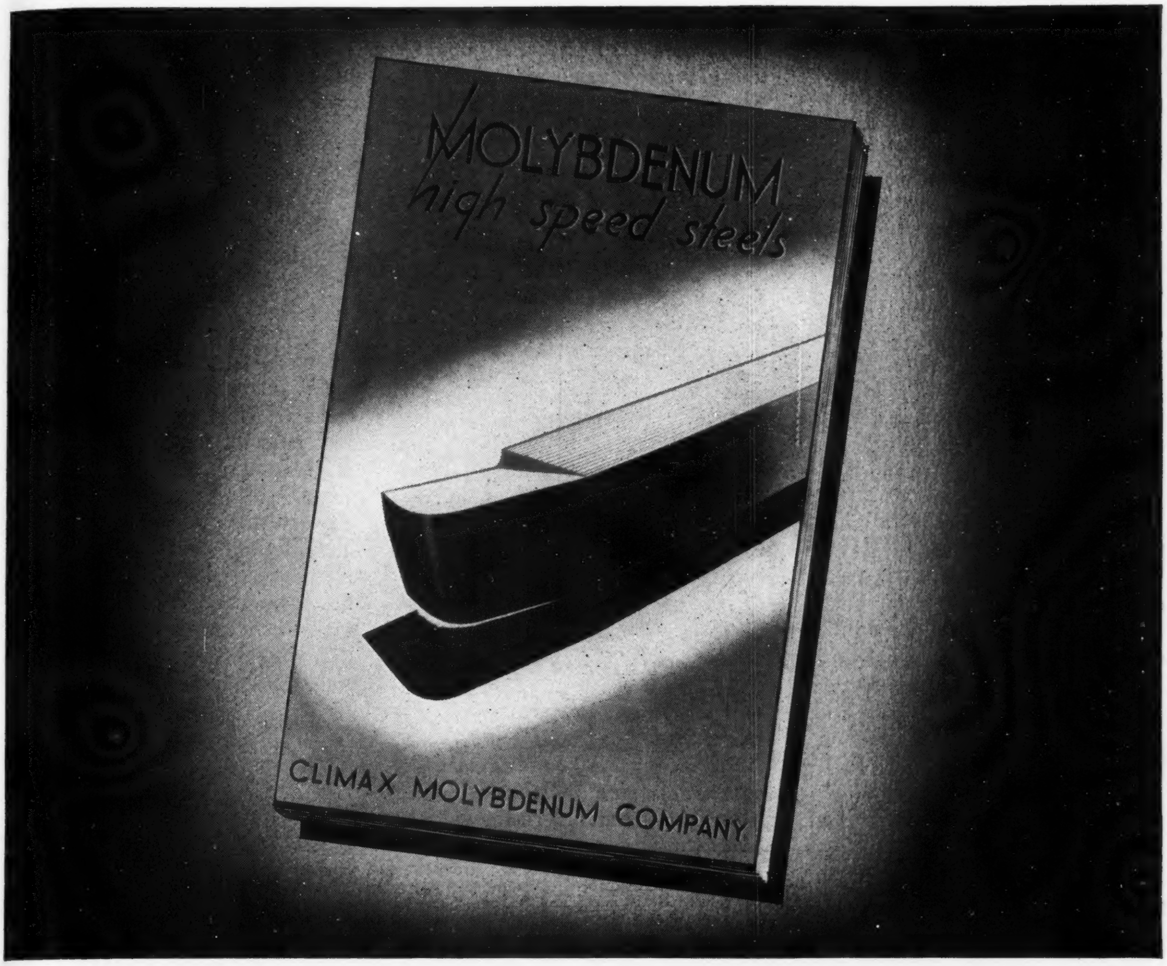
$$h + F(h_0 + C) = FQ + H - 8.937\, MFr \ldots\ldots \quad (11)$$

where h=enthalpy of air, Btu per lb.; H=enthalpy of products of combustion, Btu per lb. of air; r=latent heat of vaporization of water vapor, Btu per lb. With h=28.8, H=32.73, and r=1059.9, 500 mph (u=733 ft. per second), T_1=520R, and the fuel described above. In each case, the absolute temperature at the end of combustion has been held at T_4=2000R. The thermal performance has then been found for different pressure ratios in the ideal compressor (different values of p_3/p_2).

A sample of the procedure follows for p_3/p_2=4.0:

Compression in ideal inlet diffuser; process 1-2. A complete conversion of velocity head under adiabatic conditions gives: $h_2=h_1 + (733)^2/50{,}000=28.8 + 10.7=$

(*Continued on page* 38)


MOLYBDENUM
high speed steels
CLIMAX MOLYBDENUM COMPANY

Jet Engines

(*Continued from page* 36)

39.5 Btu/lb; T_2=565R. For the isentropic compression of this air in the diffuser, gamma=1.40, and $p_2/p_1=(T_2/T_1)^{3.5}=1.335$.

Compression in ideal compressor; process 2-3. For this isentropic compression of air, gamma=1.40, and: $T_3=T_2\ (p_3/p_2)^{0.286}$=839R. From Fig. 2, read h_3=106 (for F=0). The work done on the air in the compressor is $W=h_3-h_2$=66.5 Btu per lb.

Combustion in ideal combustor; process 3-4. The fuel-air ratio must be such that T_4=2000R, and: $F=(H_4-h_3)/(h_0+C)=(H_4-106)/18{,}600$. F must be found by trial to satisfy the last equation; in this case F=0.0176 and H_4=432.1. (See Fig. 3).

Expansion in ideal gas turbine; process 4-5. The work delivered by the turbine must be the same as the work done on the air in the compressor, and: $H_4-H_5=h_3-h_2$; H_5=432.1—66.5=365.6; from Fig. 2, for F=0.0176 and H_5=365.6, read T_5=1770R. The pressure ratio of expansion in the ideal turbine must then be found. An approximate average value of gamma for the process 4-5 may be found as follows:

$$\frac{\gamma}{\gamma-1}=\frac{778\ (H_4-H_5)}{(1+F)(R_4)(T_4-T_5)}=\frac{(778)(66.5)}{(1.0176)(53.66)(230)}=4.125$$

and gamma=1.32. Then $p_4/p_5=(T_4/T_5)^{4.125}=1.656$.

Expansion in ideal nozzle; process 5-6. The pressure ratio of isentropic expansion in the ideal nozzle is:

$$\frac{p_5}{p_6}=\frac{(p_2/p_1)(p_3/p_2)}{p_4/p_5}=3.23$$

By trial, an approximate average value of gamma may be found for the process 5-6; in this case gamma =1.33, and: $T_6=T_5\ (p_6/p_5)^{0.248}$= 1325R. From Fig. 2, read H_6= 240.0. The ideal jet velocity is:

$$v_6=223.7\sqrt{\frac{H_5-H_6}{1+F}}=2480 \text{ ft per sec.}$$

Efficiencies. The propulsion efficiency is found from Eq. (7). With u=733, v_6=2480, and F=0.0176, the propulsion efficiency equals 0.46. The thermal efficiency is found from Eq. (8) to be equal to 0.326. The overall efficiency is found from Eq. (9) to be equal to 0.46 (0.326) =0.150.

Summary of Results for Ideal Turbo-Jet Engine

Similar calculations have been made for other compression ratios with the same air speed. The resulting efficiencies are shown by the solid lines in Fig. 4 as a function of the pressure ratio of compression in the air compressor.

As this compression ratio increases at constant air speed and with a fixed temperature at the end of combustion, the propulsion efficiency decreases and the jet velocity, thermal efficiency, and overall efficiency increase. The major increase in these last quantities, however, occurs before the pressure ratio of compression is raised much beyond 2.0. Also, as the compression ratio increases, the fuel-air ratio must be decreased to limit T_4 to 2000R; very lean mixtures are necessary for low compression ratios.

(*Continued on page* 40)

Jet Engines

(*Continued from page* 38)

Turbo-Jet Engine with Imperfections

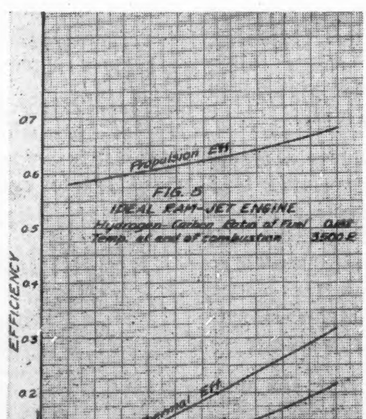
Another set of thermodynamic calculations was prepared for a turbo-jet engine with the following imperfections: (1) an isentropic efficiency of the air compressor of 0.8; (2) an isentropic efficiency of the gas turbine of 0.85; (3) a velocity coefficient of the nozzle of 0.95. Otherwise the engine is assumed to be perfect—there is no loss of head in the inlet diffuser and no pressure drop in the combustor.

The cycle of this imperfect engine is shown in Fig. 1. Dotted lines are used to represent the irreversible adiabatic processes that occur in the compressor, turbine, and nozzle.

Methods of calculation are simliar to those explained for the ideal turbo-jet engine with the following exceptions. The work required to drive the imperfect air compressor is: $W = h_{3'} - h_2 = h_3 - h_2/0.8$ Btu per lb. of air. The work delivered by the imperfect gas turbine is: $W = H_4 - H_{5'} = 0.85\ (H_4 - H_5)$ Btu per lb. of air. The actual exit velocity of the products of combustion from the nozzle is:

$$v_{7'} = 0.95(223.7)\sqrt{\frac{H_{5'} - H_7}{1+F}} \text{ ft per sec.}$$

Fig. 5. Air speed as a function of the efficiencies of an ideal ram-jet engine. with an absolute temperature at the end of combustion of 3500R. As the air speed increases, the efficiencies are seen to increase.



The propulsion efficiency, thermal efficiency, and overall efficiency of the turbo-jet engine with the three imperfections noted are shown by the dotted lines in Fig. 4, and may be compared with corresponding results for the ideal engine. It should be noted again that all these results are for an air speed of 500 mph, low altitude air composition, a fuel with a hydrogen-carbon ratio of 0.182 and a higher heating value at constant pressure and 520R of 20,000 Btu per lb., and an absolute temperature at the end of combustion (entering turbine) of 2000R.

Ideal Ram-Jet Engine

The open cycle of operation for an ideal ram-jet engine is shown in a temperature-entropy diagram of Fig. 1. An isentropic compression of the air occurs during the process 1-2 where the enthalpy of the air is increased as the velocity is decreased without losses in the ideal inlet diffuser. Process 2-8 is constant pressure combustion in the ideal combustor, and isentropic expansion 8-9 occurs in the ideal nozzle.

(*Concluded on page* 42)

Jet Engines

(*Continued from page* 40)

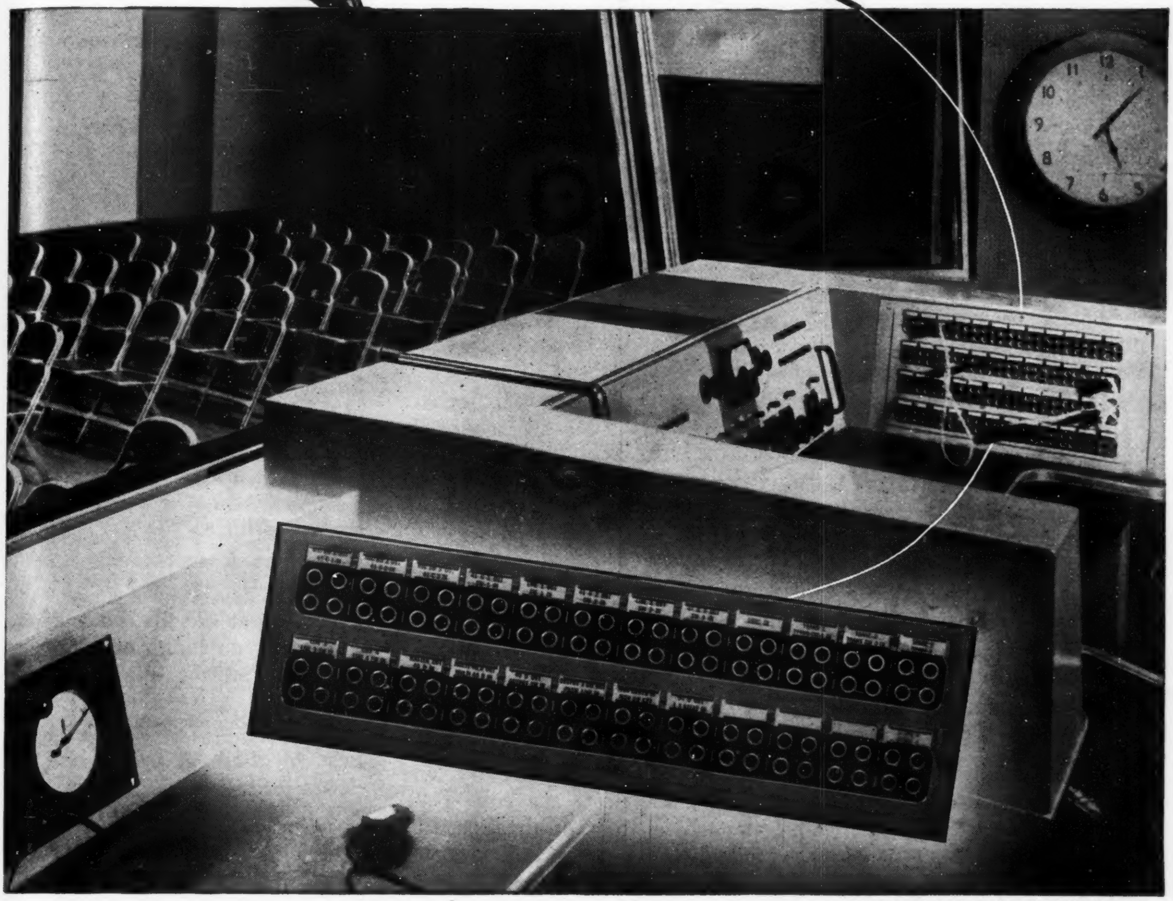
Sumary of Results for Ram-Jet Engine Performance

The important effect of air speed upon the efficiencies of an ideal ram-jet engine are as shown in Fig. 5. All these results are for one fuel, previously described, and for an absolute temperature at the end of combustion of T_8=3500R.

As the air speed increases, the exit velocity of the products of combustion, the propulsion efficiency, the thermal efficiency, and the overall efficiency increase.

As the air speed increases, the fuel-air ratio must decrease in order to maintain a fixed temperature at the end of combustion. The fuel-air ratios are larger (richer mixtures) with the ram-jet engine than with the turbo-jet engines of the previous examples, because a higher temperature is allowable at the end of the combustion process if the products of combustion do not have to pass through a gas turbine before entering the nozzle.

Plastics where plastics belong . . .
for insulation and appearance



Photograph Courtesy of Station WNEW, N.Y.C.

Synthane . . . where synthane belongs

USES for Synthane laminated plastics are almost unlimited because of their combination of chemical, electrical and mechanical properties. Synthane is corrosion and moisture resistant, light in weight, quickly and easily machined. It is also hard, dense, strong, one of the best electrical insulators known. The "set" plastic, Synthane is stable over a wide range of temperatures.

An interesting example of Synthane at work is this jack panel which enables the broadcast technician to plug in or transfer amplifiers, microphones, telephone lines or other equipment, giving the input system greater operating flexibility. This is an appropriate job for our type of plastics because Synthane is an excellent electrical insulator, and contributes to the attractiveness of the control booth. Synthane Corporation, 14 River Road, Oaks, Pa.

SYNTHANE
S

DESIGN • MATERIALS • FABRICATION • SHEETS • RODS • TUBES • FABRICATED PARTS • MOLDED-MACERATED • MOLDED-LAMINATED

STRESS *and* STRAIN...

A C.E. suddenly decided to give up building bridges and start an electric eel farm. To start, he bought a big bowl and one male and one female eel. He'd thought he had all the ingredients, but the eel population failed to increase.

Finally he got pretty angry at the whole thing and shouted into the bowl, "Looka here, you eels! I paid big money for you two and I've fed you the best seaweed I can get, but I've still got just two eels. What's the matter?"

"Well, sir," explained the male eel, "It's this way: I'm A.C. and she's D.C."

* * *

A young man whose father had been hanged was filling out a life insurance form. After the usual questions about hereditary diseases, there was one asking for the cause of death of his parents.

He thought for a while and finally put down this answer: "Mother died of pneumonia. Father was taking part in a public function when the platform gave way."

* * *

"What's in the fancy vase on the mantle?"

"My husband's ashes."

"Oh, I'm sorry. How long has he been dead?"

"He's not. Just too lazy to find an ash tray."

* * *

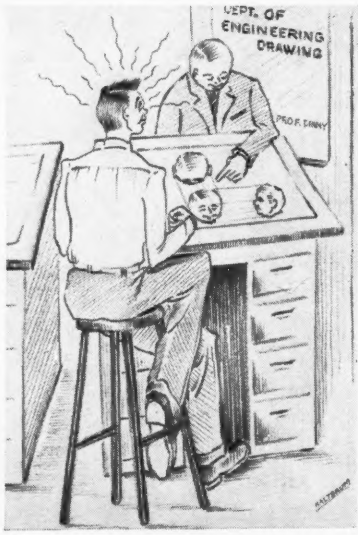
His wife was a WAVE
And he waved at a WAC
The WAC was in front
But his WAVE was in back
Instead of a wave from the WAC
Be it said
He got a whack from the WAVE
He had wed.

* * *

Clerk: *"Shopping bags?"*

Three girls: *"No, we're just looking."*

Then there was the moron who sprayed his garden with alcohol so he could raise stewed tomatoes.



"—And what is that a projection of?"

A dozen local college boys were coming home from a party one night plastered to the gills. They stopped in front of the house of one of their number and called for the father. "Will you please do us a favor?" said one.

"What do you want?" replied the father.

"Will you please come out here and pick out Charlie so the rest of us can go home?"

* * *

An engineer was talking to a Sociology Prof.

S.P.: "Who is the more satisfied, a man with a million dollars or a man with six children?"

Engineer: "A man with six children."

S.P.: "Can you prove it?"

Engineer: "Why, a man with a million dollars wants more!"

If "Out of Phase" can have definitions, so can we. The following list is guaranteed to be useful in Physics 118, E.E. 4981, Electronics Lab, and in nauseating your friends. If the results are not as advertised, tear off the top of Sibley dome and send it in with your name and address, and your subscription price will be refunded.

* * *

Analysis—That which we copy from our neighbors' papers.

Autotransformer — The transformer you ought to get in place of the one that burned out.

Class A Transmitter—One out of a hundred professors.

Copper Loss—The death rate in the police force.

Damper—A wet blanket at a party.

Equivalent Circuit—The one you think you can figure out that you substitute for the one you know you can't.

Push-Pull — The state of mind brought about by exams and the desire for a degree.

Screen Grid—Used for showing football movies.

Sharp Cutoff—"NO!"

Standing Waves—Navy women at attention.

Torsional Vibration—The effect of home-made hooch.

Zig Zag Connection—The Lehigh Valley.

* * *

ROTC Captain: *"What is the best method of preventing diseases caused by biting insects?"*

Frosh Cadet: *"Don't bite the insects."*

* * *

"Frequent water drinking," says the specialist, "prevents you from becoming stiff in the joints."

"Yes, but some of the joints don't serve water."

DU PONT Digest

For Students of Science and Engineering

Determination of spinning tension by C. S. McCandlish, Chemical Engineer, Northwestern University '44, and A. I. Whitten, Ph. D., Physical Chemistry, Duke University '35.

Many Theoretical and Applied Studies Behind Development of "Cordura" Rayon

Stronger, lighter tires made possible by teamwork of Du Pont chemists, engineers, and physicists

On the surface, the viscose process for rayon seems fairly simple. Cellulose from cotton or wood is steeped in NaOH to give alkali cellulose, which is treated with CS_2 to form cellulose xanthate. Adding NaOH gives molasses-like "viscose," which is squirted through spinnerets into a coagulating bath of acid and salt to form from 500 to 1,000 filaments simultaneously:

$$\underset{\text{(cellulose)}}{R^*\text{-OH}} + NaOH \longrightarrow \underset{\text{(alkali cellulose)}}{R\text{-ONa}} + H_2O$$

$$R\text{-ONa} + CS_2 \longrightarrow \underset{\text{(cellulose xanthate)}}{R\text{-O-}\overset{\overset{\displaystyle S}{\|}}{C}\text{-SNa}}$$

$$R\text{-O-}\overset{\overset{\displaystyle S}{\|}}{C}\text{-SNa} + H_2SO_4 \longrightarrow \underset{\text{(cellulose)}}{R\text{-OH}} + CS_2 + NaHSO_4$$

$$R^* = C_6H_7O_2(OH)_2$$

Du Pont scientists were working to improve on the properties of rayon made by this process when, in 1928, a rubber company asked for a rayon yarn that would be stronger than cotton for tire cords. The problem was given to a team of organic, physical, and analytical chemists, chemical and mechanical engineers, and physicists.

Theoretical and Applied Studies

In developing the new improved rayon, a number of theoretical studies were carried out: for example, (1) rates of diffusion of the coagulating bath into the viscose filaments, (2) the mechanism of coagulation of viscose, (3) the relationship between fiber structure and properties by x-rays, and (4) a phase study of spinning baths.

Concurrently, applied research was necessary. This proceeded along many lines, but the main problem was to perfect the spinning technique. It was known that a short delay in the bath between the spinneret and the stretching operation allowed greater tension on the filaments. Du Pont engineers, therefore, designed a series of rollers, each revolving faster than the previous one, to increase the tension gradually.

In addition, a textile finish was developed that combined just the right amount of plasticizing action and lubricating power, allowing the filaments to twist evenly in forming the cord. A new adhesive was prepared to join the yarn with rubber. New twisting techniques for cord manufacture were found, since the usual methods caused loss in rayon strength.

Engineering Problems Solved

Chemical and mechanical engineers were faced with the design and operation of equipment for more than 15 different types of unit operations. Equipment had to operate every minute of the day, yet turn out perfectly uniform yarn. It was necessary to filter the viscose so carefully that it would pass through spinning jet holes less than 4/1000th of an inch without plugging. Some of the most exacting temperature and humidity control applications in the chemical industry were required.

Out of this cooperation among scientists—ranging from studies of cellulose as a high polymer to design of enormous plants—came a new product, "Cordura" high-tenacity rayon, as strong as mild steel, yet able to stand up under repeated flexing. Today, this yarn is almost 100% stronger than 20 years ago. Tires made with it are less bulky and cooler running, yet give greater mileage under the most punishing operating conditions. In "Cordura," men of Du Pont have made one of their most important contributions to the automotive industry.

Questions College Men ask about working with Du Pont

How are new men engaged?

Most college men make their first contact through Personnel Division representatives who visit many campuses periodically. Those interested may ask their college authorities when Du Pont men will next conduct interviews. Write for booklet, "The Du Pont Company and the College Graduate," 2518 Nemours Building, Wilmington 98, Del.

DU PONT

REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING ...*THROUGH CHEMISTRY*

More facts about Du Pont—Listen to "Cavalcade of America" Monday Nights, NBC Coast to Coast

Rayon spinning machine. The spinning solution is pumped through a spinneret immersed in a hardening bath. Filaments are guided over a rotating glass wheel and down into the whirling collecting bucket. Inset shows close-up of spinneret; each hole forms a filament.

Index to Volume 13

Articles

Authors

Personalities